

DTIC FILE COPY

Naval Environmental Prediction Research Facility  
Monterey, CA 93943-5006



1

Contractor Report CR 88-05 May 1988

AD-A198 912

# SEVERE WEATHER GUIDE MEDITERRANEAN PORTS

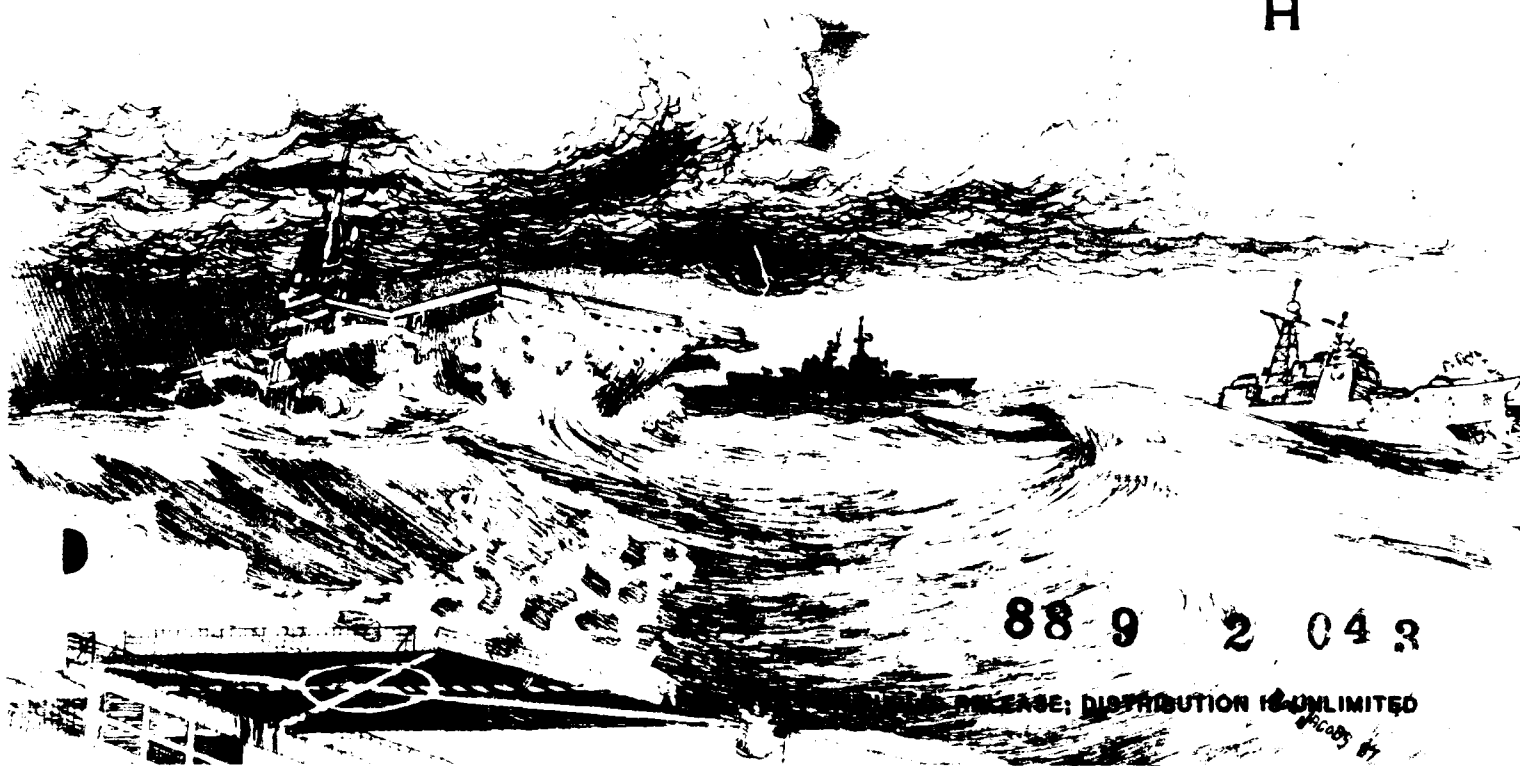
## 17. PALMA, MALLORCA

DTIC

ELECTE

SEP 02 1988

S H D



88 9 2 04 3

UNCLASSIFIED; DISTRIBUTION IS UNLIMITED

QUALIFIED REQUESTORS MAY OBTAIN ADDITIONAL COPIES  
FROM THE DEFENSE TECHNICAL INFORMATION CENTER.  
ALL OTHERS SHOULD APPLY TO THE NATIONAL TECHNICAL  
INFORMATION SERVICE.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

ADA 198912

## REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b RESTRICTIVE MARKINGS		
2a SECURITY CLASSIFICATION AUTHORITY			3 DISTRIBUTION AVAILABILITY OF REPORT Approved for public release; distribution is unlimited		
2b DECLASSIFICATION/DOWNGRADING SCHEDULE					
4 PERFORMING ORGANIZATION REPORT NUMBER(S) CR 88-05			5 MONITORING ORGANIZATION REPORT NUMBER(S) CR 88-05		
6a NAME OF PERFORMING ORGANIZATION Science Applications International Corp.		6b OFFICE SYMBOL (if applicable)	7a NAME OF MONITORING ORGANIZATION Naval Environmental Prediction Research Facility		
6c ADDRESS (City, State, and ZIP Code) 205 Montecito Ave. Monterey, CA 93940			7b ADDRESS (City, State, and ZIP Code) Monterey, CA 93943-5006		
8a NAME OF FUNDING/SPONSORING ORGANIZATION Commander, Naval Oceanography Command		8b OFFICE SYMBOL (if applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00228-84-D-3187		
9a ADDRESS (City, State, and ZIP Code) NSTL, MS 39529-5000			10 SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO	PROJECT NO	TASK NO
			WORK UNIT ACCESSION NO		
11 TITLE (Include Security Classification) Severe Weather Guide - Mediterranean Ports - 17. Palma, Mallorca (U)					
12 PERSONAL AUTHOR(S) Englebreton, Ronald E. (LCDR,USN,Ret.) and Gilmore, Richard D. (CDR,USN,Ret.)					
13a TYPE OF REPORT Final		13b TIME COVERED FROM 9/13/84 TO 11/1/86		14 DATE OF REPORT (Year, Month, Day) 1988, May	
15 PAGE COUNT 63					
16 SUPPLEMENTARY NOTATION Funding source: O&M,N-1					
17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP			
04	02		Storm haven Mediterranean meteorology		
			Palma, Mallorca port Mediterranean oceanography		
19 ABSTRACT (Continue on reverse if necessary and identify by block number) This handbook for the port of Palma, Mallorca, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.					
20 DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS			21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a NAME OF RESPONSIBLE INDIVIDUAL Perryman, Dennis G., contract monitor			22b TELEPHONE (Include Area Code) (408) 647-4709		22c OFFICE SYMBOL O&M,N-1

## CONTENTS

Foreword . . . . .	iii
Preface . . . . .	v
Record of Changes . . . . .	vii
 1. GENERAL GUIDANCE . . . . .	 1-1
1.1 Design . . . . .	1-1
1.1.1 Objectives . . . . .	1-1
1.1.2 Approach . . . . .	1-1
1.1.3 Organization . . . . .	1-2
1.2 Contents of Specific Harbor Studies . . . . .	1-3
 2. Captain's Summary . . . . .	 2-1
 3. General Information . . . . .	 3-1
3.1 Geographic Location . . . . .	3-1
3.2 Qualitative Evaluation of Port of Palma as a Haven . . . . .	3-4
3.3 Currents and Tides . . . . .	3-4
3.4 Visibility . . . . .	3-4
3.5 Hazardous Conditions . . . . .	3-5
3.6 Harbour Protection . . . . .	3-9
3.6.1 Wind and Weather . . . . .	3-9
3.6.2 Waves . . . . .	3-10
3.6.3 Wave Data Uses and Considerations . . . . .	3-15
3.7 Protective/Mitigating Measures . . . . .	3-16
3.7.1 Sortie/Remain in Port . . . . .	3-16
3.7.2 Moving to New Anchorage . . . . .	3-16
3.7.3 Scheduling . . . . .	3-16
3.8 Local Indicators of Hazardous Weather Conditions . . . . .	3-17
3.9 Summary of Problems, Actions, and Indicators . . . . .	3-18
 References . . . . .	 3-23
 Appendix A -- General Purpose Oceanographic Information . . . . .	 A-1

## FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (COMNAVOCEANCOM) requirements validated by the Chief of Naval Operations (OP-096).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to Naval Oceanography Command Center (NAVOCEANCOMCEN), Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

W. L. SHUTT  
Commander, U.S. Navy



Accession For		
NTIS GRA&I		<input checked="" type="checkbox"/>
DTIC TAB		<input type="checkbox"/>
Unannounced		<input type="checkbox"/>
Distribution		
By		
Availability Codes		
Dist. Special		
A-1		

# PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT	1990	PORT
1	GAETA, ITALY		BENIDORM, SPAIN
2	NAPLES, ITALY		ROTA, SPAIN
3	CATANIA, ITALY		TANGIER, MOROCCO
4	AUGUSTA BAY, ITALY		PORT SAID, EGYPT
5	CAGLIARI, ITALY		ALEXANDRIA, EGYPT
6	LA MADDALENA, ITALY		ALGIERS, ALGERIA
7	MARSEILLE, FRANCE		TUNIS, TUNISIA
8	TOULON, FRANCE		GULF HAMMAMET, TUNISIA
9	VILLEFRANCHE, FRANCE		GULF OF GABES, TUNISIA
10	MALAGA, SPAIN		SOUDA BAY, CRETE
11	NICE, FRANCE		
12	CANNES, FRANCE	1991	PORT
13	MONACO		
14	ASHDOD, ISRAEL		PIRAEUS, GREECE
15	HAIFA, ISRAEL		KALAMATA, GREECE
16	BARCELONA, SPAIN		THESSALONIKI, GREECE
17	PALMA, SPAIN		CORFU, GREECE
18	IBIZA, SPAIN		KITHIRA, GREECE
19	POLLENSA BAY, SPAIN		VALETTA, MALTA
20	LIVORNO, ITALY		LARNACA, CYPRUS
21	LA SPEZIA, ITALY		
22	VENICE, ITALY	1992	PORT
23	TRIESTE, ITALY		
24	CARTAGENA, SPAIN		ANTALYA, TURKEY
25	VALENCIA, SPAIN		ISKENDERUN, TURKEY
	SAN REMO, ITALY		IZMIR, TURKEY
	GENOA, ITALY		ISTANBUL, TURKEY
			GOLCUK, TURKEY
			GULF OF SOLLUM
1989	PORT		
	SPLIT, YUGOSLAVIA		
	DUBROVNIK, YUGOSLAVIA		
	TARANTO, ITALY		
	PALERMO, ITALY		
	MESSINA, ITALY		
	TAORMINA, ITALY		
	PORTO TORRES, ITALY		

## PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

## RECORD OF CHANGES

[illegible]

## 1. GENERAL GUIDANCE

### 1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

#### 1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

#### 1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

- A. A literature search for reference material was performed.
- B. Cruise reports were reviewed.
- C. Navy personnel with current or previous area experience were interviewed.
- D. A preliminary report was developed which included questions on various local conditions in specific harbors.

- E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained.
- F. The cumulative information was reviewed, combined, and condensed for harbor studies.

### 1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

- A. a brief narrative summary of environmental hazards,
- B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,
- C. local wind wave conditions, and
- D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

## 1.2. CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested precautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

## 2. CAPTAIN'S SUMMARY

Palma is located approximately 110 n mi south of Barcelona and 140 n mi east of Valencia, Spain, on the island of Mallorca in the Balearic Islands (Figure 2-1).

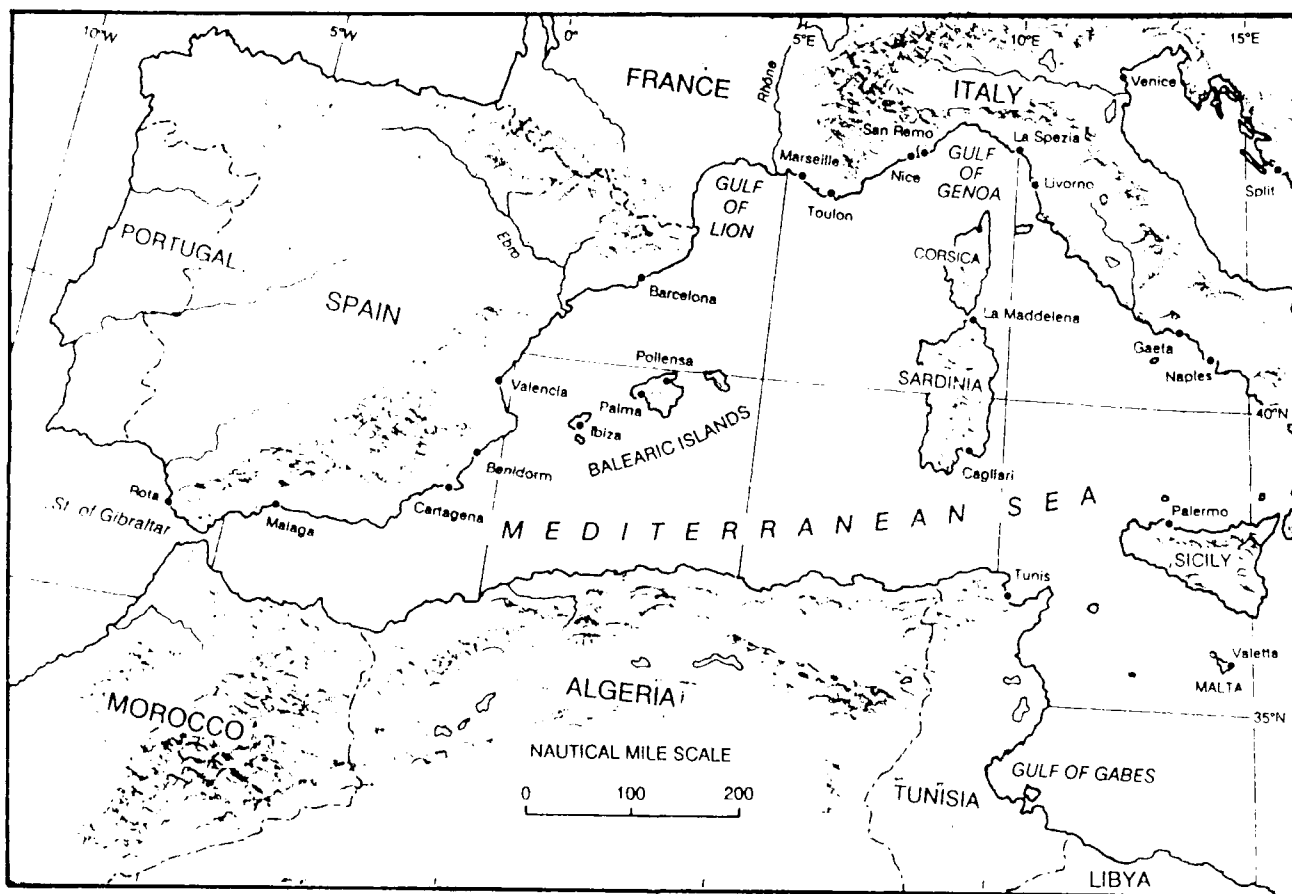


Figure 2-1. Western Mediterranean Sea

The Port of Palma is situated at the head of the Bay of Palma on the south coast of the southwestern portion of the island (Figure 2-2).

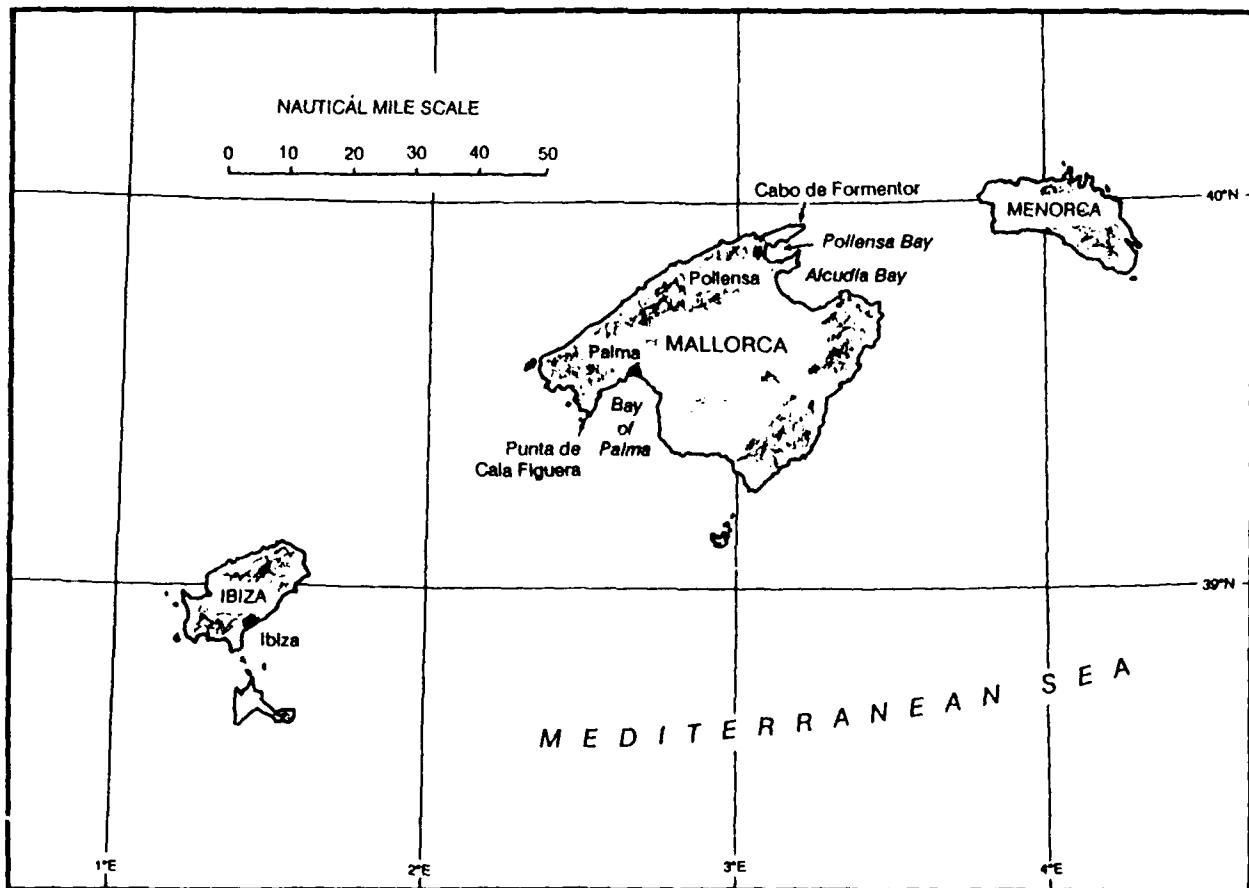


Figure 2-2. Balearic Islands.

The port is medium sized, and capable of accommodating several ships with drafts to 40 ft (12 m). The inner harbor is spacious and well dredged with ample maneuvering room (FICEURLANT, 1987). It is sheltered on the south and east by breakwaters, and on the west and north by land (Figure 2-3). Large ships, including aircraft carriers, are assigned to an anchorage located on a bearing of 151°, 1,600 yd (1,463 m) from the head of the west breakwater, Dique del Oeste.

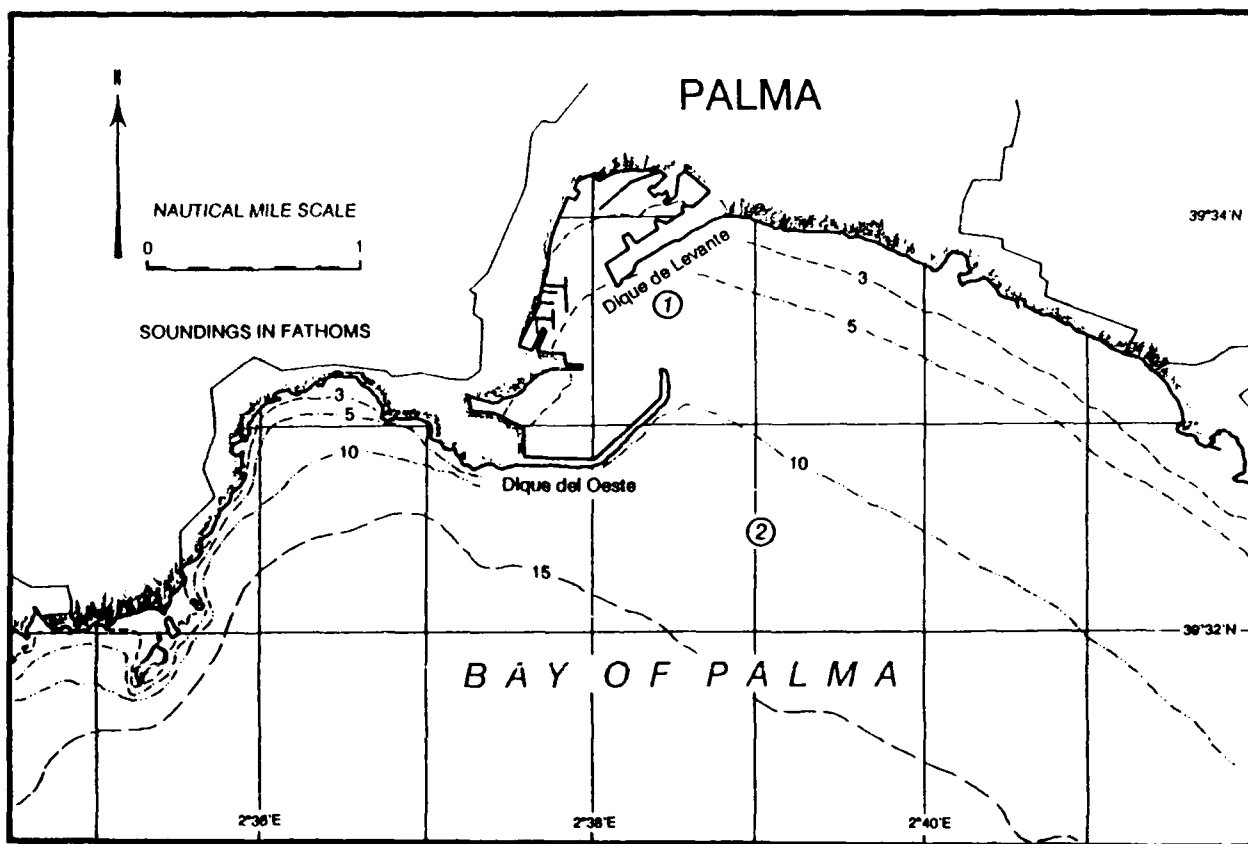


Figure 2-3. Port of Palma de Mallorca.

The inner harbor of the Port of Palma is well protected. According to local authorities, winds and waves do not necessitate protective measures within the harbor. A tall quay wall on Dique del Oeste provides ample shelter for moored vessels.

The anchorage is exposed to some of the conditions from which the inner harbor is sheltered. Southeasterly waves (both sea and swell) of 10 to 13 ft (3 to 4 m) reach the anchorage about 7 days per year. Usually caused by Scirocco winds (locally called Xaloc), the event is difficult to predict. Southwesterly winds can generate waves which reach Punta de Cala Figuera (about 8 n mi southwest of the port) with heights of 10 to 13 ft (3 to 4 m), but the waves diminish somewhat before they reach the anchorage. The anchorage has a good mud and sand bottom, with 90 to 100 fm of chain on a single anchor recommended. Local authorities state that in the past 15 years, no ship has been moved from the anchorage due to bad weather.

There are no significant currents in the Bay of Palma. Tides are negligible. There is no astronomical tide but a barometric tide exists, with a variation of 6 to 8 inches (15 to 20 cm). High pressure results in a lowering of the water level, while low pressure raises it.

Specific hazardous environmental conditions, vessel situations, and suggested precautionary/evasive action scenarios are summarized in Table 2-1.

Table 2-1. Summary of hazardous weather con

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VES SITL
<p>1. <u>SE'ly winds/waves</u> - Normally occurs about 7 times/year at Palma.</p> <ul style="list-style-type: none"> <li>* Locally called "Xaloc."</li> <li>* Usually caused by synoptic scale SE flow.</li> <li>* Commonly of Scirocco origin.</li> <li>* Occurs in warm sectors of cyclones passing north of Palma.</li> <li>* May bring very warm temperatures to Palma.</li> <li>* May be accompanied by low clouds.</li> <li>* Waves of 10 to 13 ft (3 to 4 m) may reach anchorage.</li> </ul>	<p><u>Advance warning</u></p> <ul style="list-style-type: none"> <li>* Evolving synoptic situation which will place Palma in warm sector of cyclone passing north of area.</li> <li>* SE swell may arrive before winds that generated it.</li> <li>* When water level in harbor increases, a S'ly wind can be expected in 5-6 hr. NOTE: This guideline must be used with caution since the water level also varies with barometric pressure changes.</li> </ul> <p><u>Duration</u></p> <ul style="list-style-type: none"> <li>* Conditions will abate gradually as cyclone moves east and Palma is no longer in wind field.</li> <li>* Swell will diminish gradually after wind field over the fetch area weakens or moves. With time, swell will diminish in height and have increasingly shorter periods.</li> </ul>	<p>(1) P</p> <p>(2) F</p> <p>(3) F</p> <p>(4) F</p>
<p>2. <u>SW'ly winds/waves</u> - Commonly precedes cold fronts crossing the Iberian Peninsula.</p> <ul style="list-style-type: none"> <li>* Called Vendaval at many locations.</li> <li>* May generate waves of 10 to 13 ft (3 to 4 m) which diminish somewhat before reaching anchorage.</li> <li>* Short duration 20 kt winds can raise 5 ft seas in anchorage.</li> <li>* May be accompanied by rain.</li> </ul>	<p><u>Advance warning</u></p> <ul style="list-style-type: none"> <li>* SW'ly winds (Vendaval) will precede cold fronts moving east across Iberian Peninsula.</li> <li>* When water level in harbor increases, a S'ly wind can be expected in 5-6 hr. NOTE: This guideline must be used with caution since the water level also varies with barometric pressure changes.</li> </ul> <p><u>Duration</u></p> <ul style="list-style-type: none"> <li>* Winds will veer to west at frontal passage.</li> <li>* SW swell may persist after frontal passage, but will diminish gradually in height and have increasingly shorter periods.</li> </ul>	<p>(1) F</p> <p>(2) F</p> <p>(3) F</p> <p>(4) F</p>

other conditions for the Port of Palma, Mallorca.

VESSEL/LOCATION SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
<p>(1) <u>Moored - inner harbor.</u></p> <p>(2) <u>Anchored.</u></p> <p>(3) <u>Arriving/departing.</u></p>	<p>(a) NONE</p> <p>(a) <u>Winds and waves reach the anchorage.</u></p> <ul style="list-style-type: none"> <li>* Anchored vessels should be able to remain, using single anchor with 90-100 fm chain on good bottom of mud and sand.</li> <li>* If a move is indicated, Pollensa Bay or Alcudia Bay on NE side of Mallorca would provide better protection from waves. But S'ly winds funnel to Pollensa Bay and reach the anchorage as SW force 5 to 6 (17-21 to 27-28 kt). May cause ships to drag anchor. Alcudia Bay provides more room for dragging before hazards are encountered.</li> </ul> <p>(a) <u>Winds and waves reach the anchorage but have no effect on the inner harbor.</u></p> <ul style="list-style-type: none"> <li>* Inbound/outbound units should be able to proceed to/from the inner harbor without difficulty because adequate maneuvering room is available inside breakwaters.</li> <li>* Ships arriving at anchorage should experience no significant problems due to good holding provided by mud and sand bottom.</li> <li>* If more protected waters are required, the anchorages at Pollensa Bay or Alcudia Bay on NE side of Mallorca should be considered.</li> <li>* Small boat operations to/from the inner harbor and the anchorage may be hazardous.</li> </ul>
<p>(4) <u>Small boats.</u></p>	<p>(a) <u>Small boats should experience no significant difficulty operating in the inner harbor but operations outside the protection of the breakwaters may be hazardous.</u></p> <ul style="list-style-type: none"> <li>* Boat runs to/from the inner harbor and anchorage may have to be curtailed.</li> <li>* During winds of force 5 (17-21 kt) or greater, with minimum swell, ships can maneuver such that boating operations can be conducted on their lee side with little problem. Higher swell negates possibility.</li> </ul>
<p>1. <u>Moored - inner harbor.</u></p> <p>2. <u>Anchored.</u></p>	<p>(a) NONE</p> <p>(a) <u>Winds and waves reach the anchorage.</u></p> <ul style="list-style-type: none"> <li>* Anchored vessels should be able to remain, using single anchor with 90-100 fm chain on good bottom of mud and sand.</li> <li>* If a move is indicated, Pollensa Bay or Alcudia Bay on NE side of Mallorca would provide better protection from waves. But S'ly winds funnel to Pollensa Bay and reach the anchorage as SW force 5 to 6 (17-21 to 22-28 kt). May cause ships to drag anchor. Alcudia Bay provides more room for dragging before hazards are encountered.</li> </ul>
<p>(3) <u>Arriving/departing.</u></p>	<p>(a) <u>Winds and waves reach the anchorage but have no effect on the inner harbor.</u></p> <ul style="list-style-type: none"> <li>* Inbound/outbound units should be able to proceed to/from the inner harbor without difficulty because adequate maneuvering room is available inside breakwaters.</li> <li>* Ships arriving at anchorage should experience no significant problems due to good holding provided by mud and sand bottom.</li> <li>* If more protected waters are required, the anchorages at Pollensa Bay or Alcudia Bay on NE side of Mallorca should be considered.</li> <li>* Small boat operations to/from the inner harbor and the anchorage may be hazardous.</li> </ul>
<p>(4) <u>Small boats.</u></p>	<p>(a) <u>Small boats should experience no significant difficulty operating in the inner harbor but operations outside the protection of the breakwaters may be hazardous.</u></p> <ul style="list-style-type: none"> <li>* Boat runs to/from the inner harbor and anchorage may have to be curtailed.</li> <li>* During winds of force 5 (17-21 kt) or greater, with minimum swell, ships can maneuver such that boating operations can be conducted on their lee side with little problem. Higher swell negates possibility.</li> </ul>

Table 2-1. (Conti

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL/ SITUATION
<p>3. <u>Sea breeze</u> - Common occurrence on warm days.</p> <ul style="list-style-type: none"> <li>* Locally called "Eabat," S wind starts at noon.</li> <li>* Usually reaches force 3 to 4 (7-10 to 11-16 kt) during afternoon.</li> <li>* Can raise a 3 ft (about 1 m) sea in anchorage.</li> <li>* Calms at sunset.</li> <li>* Most common during March to October period but can occur all months.</li> </ul>	<p><u>Advance warning</u></p> <ul style="list-style-type: none"> <li>* To be expected on all warm days - very consistent.</li> </ul> <p><u>Duration</u></p> <ul style="list-style-type: none"> <li>* Noon to sunset; strongest in mid to late afternoon.</li> </ul>	<p>(1) <u>Small t</u></p>

(Continued)

VESSEL/LOCATION SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
(1) <u>Small boats.</u>	(a) <u>Small boat operations will be only minimally affected.</u> * Chippy wave conditions to 3 ft (about 1 m) may be raised in the anchorage by late afternoon. * Inner harbor operations should not be adversely affected.

For estimating shallow water wave heights, two points have been selected (Figure 2-3). Point 1 is near the harbor entrance and Point 2 is about 1600 yd south-southeast of the head of Digue del Oeste where large ships anchor.

Table 2-2 provides the height ratio and direction of shallow water waves to expect at Points 1 and 2 when the deep water wave conditions are known.

The Palma Point 2 conditions are found by entering Table 2-2 with the forecast or known deep water wave direction and period. In the following example, the height is determined by multiplying the deep water height (8 ft) by the ratio of shallow to deep height (.9).

Example: Use of Table 2-2 for Palma Point 2.

Deep water wave forecast as provided by a forecast center or a reported/observed deep water wave condition:

8 feet, 10 seconds, from 210°.

The expected wave condition at Palma Point 2, as determined from Table 2-2:

7 feet, 10 seconds, from 210°.

NOTE: Wave periods are a conservative property and, therefore, remain constant when waves move from deep to shallow water, but speed, height, and steepness change.

Table 2-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 2-3 for location of the points).

FORMAT: Shallow Water Direction  
Wave Height Ratio: (Shallow Water/Deep Water)

PALMA POINT 1: (Near Inner Harbor Entrance) 35 ft depth

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
150°	150° .3	150° .3	155° .4	160° .4	170° .3	180° .2
180°	155° .3	155° .4	160° .5	160° .7	180° .5	180° .2
210°	185° .4	170° .4	160° .7	170° .6	175° .8	185° .6
240°	190° .2	190° .1	195° .2	195° .2	195° .2	195° .2

PALMA POINT 2: (Fleet Anchorage) 75 ft depth

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
150°	170° .8	170° .8	175° .5	175° .4	180° .4	185° .4
180°	180° .8	185° .8	190° .8	190° .7	195° .5	190° .2
210°	210° .9	210° .9	210° .9	210° .9	205° .9	205° .9
240°	210° .8	210° .7	220° .5	225° .7	225° .5	225° .4

The local wind-generated wave conditions for the anchorage area identified as Points 1 and 2 are given in Table 2-3. All heights refer to the significant wave height (average of the highest 1/3 waves). Enter the local wind speed and direction in this table to obtain the minimum duration in hours required to develop the indicated fetch limited sea height and period. The time to reach fetch limited height is based on an initial flat ocean. When starting from a pre-existing wave height, the time to fetch limited height will be shorter.

Table 2-3. Palma. Local wind waves for fetch limited conditions at Points 1 and 2 (based on JONSWAP model).

Points 1 & 2.

Format: height (feet)/period (seconds)  
time (hours) to reach fetch limited height

Direction and\ Fetch \		Local Wind Speed (kt)						
Length \		14	16	18	24	30	36	42
(n mi)								
SE		<2 ft	<2 ft	<2 ft	2/3	3/3-4	3-4/3-4	4/4
6 n mi					1-2	1-2	1-2	1-2
SW		<2 ft	<2 ft	<2 ft	2-3/3-4	3-4/3-4	3-4/4	4-5/4-5
8 n mi					1-2	1-2	1-2	1-2
S*		2-3/4-5	3/4-5	3-4/5	5/5-6	6/6	7/6	8/6-7
30 n mi		3	4	4	4	3-4	3-4	3

\* 30 n mi is considered the usual fetch length for a sea breeze event.

Example:  
To the southwest (225°) of Point 2 there is about a 8 n mi fetch (Figure 2-2). Given a southwest wind at 36 kt, the sea will have reached 3-4 feet with a period of 4 seconds within 1-2 hours. Wind waves will not grow beyond this condition unless the wind speed increases or the direction changes to one over a longer fetch length. If the wind waves are superimposed on deep water swell, the combined height may change in response to changing swell conditions. Wind wave directions are assumed to be the same as the wind direction.

Climatological factors of shallow water waves, as described by percent occurrence, average duration, and period of maximum energy (period at which the most energy is focused for a given height), are given in Table 2-4. See Appendix A for discussion of wave spectrum and energy distribution. These data are provided by season for two ranges of heights: greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m).

Table 2-4. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m) by climatological season.

PALMA POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	1	<< 1	<< 1	1
Average Duration (hr)	11	NA	NA	12
Period Max Energy(sec)	10-11	NA	NA	10
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	NA	NA	NA	NA
Average Duration (hr)	NA	NA	NA	NA
Period Max Energy(sec)	NA	NA	NA	NA
PALMA POINT 2:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	9	9	3	10
Average Duration (hr)	12	13	17	10
Period Max Energy(sec)	9-10	9-10	9-10	9-10
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	1	<< 1	<< 1	1
Average Duration (hr)	12	NA	NA	6
Period Max Energy(sec)	11	NA	NA	10

## SEASONAL SUMMARY OF PALMA HAZARDOUS WEATHER CONDITIONS

### WINTER (mid-January thru March):

- \* Southerly waves Xaloc/Scirocco 10 to 13 ft (3 to 4m) occur several times a year with cyclones centered to the north.
- \* Levante, easterly winds: rainy conditions can last for about 3 days.
- \* Visibility: worst of year; averages 5 days where visibility is less than 100 yards
- \* Northwestern squalls, winds 34 to 40 kt, occur 2 to 3 times a month during January and February.

### SPRING (April to mid-June):

- \* Winter-like conditions continue through April.
- \* Sea breeze, "Embat", daily event: starts near noon, calms at sunset. Southerly 7 to 16 kt; raises 3 ft waves in roadstead.

### SUMMER (mid-June thru September):

- \* Sea breeze, "Embat", daily event; starts near noon, calms at sunset. Southerly 7 to 16 kt, raises 3 ft waves in roadstead.
- \* Rare events: gale force southerly winds (34 to 40 kt) when gradient winds reinforce sea breeze. Strongest winds of short duration during afternoons.

### AUTUMN (October thru mid-January):

- \* Winter type winds return in November.
- \* Levante: easterlies warning of rainy conditions for 3-day periods on the increase.
- \* Heavy northwesterly squalls of winter possible near end of season.

NOTE: For more detailed information on hazardous weather conditions, see previous Summary Table in this section and Hazardous Weather Summary in Section 3.

#### REFERENCES

FICEURLANT, 1987: Port Directory for Palma (1985),  
Balearic Islands. Fleet Intelligence Center Europe and  
Atlantic, Norfolk, Virginia.

### 3. GENERAL INFORMATION

This section is intended for Fleet meteorologists/oceanographers and staff planners. Paragraph 3.5 provides a general discussion of hazards and Table 3-5 provides a summary of vessel locations/situations, potential hazards, effect-precautionary/evasive actions, and advance indicators and other information about potential hazards by season.

#### 3.1 Geographic Location

Palma is located approximately 110 n mi south of Barcelona and 140 n mi east of Valencia, Spain on the island of Mallorca in the Balearic Islands (Figure 3-1).

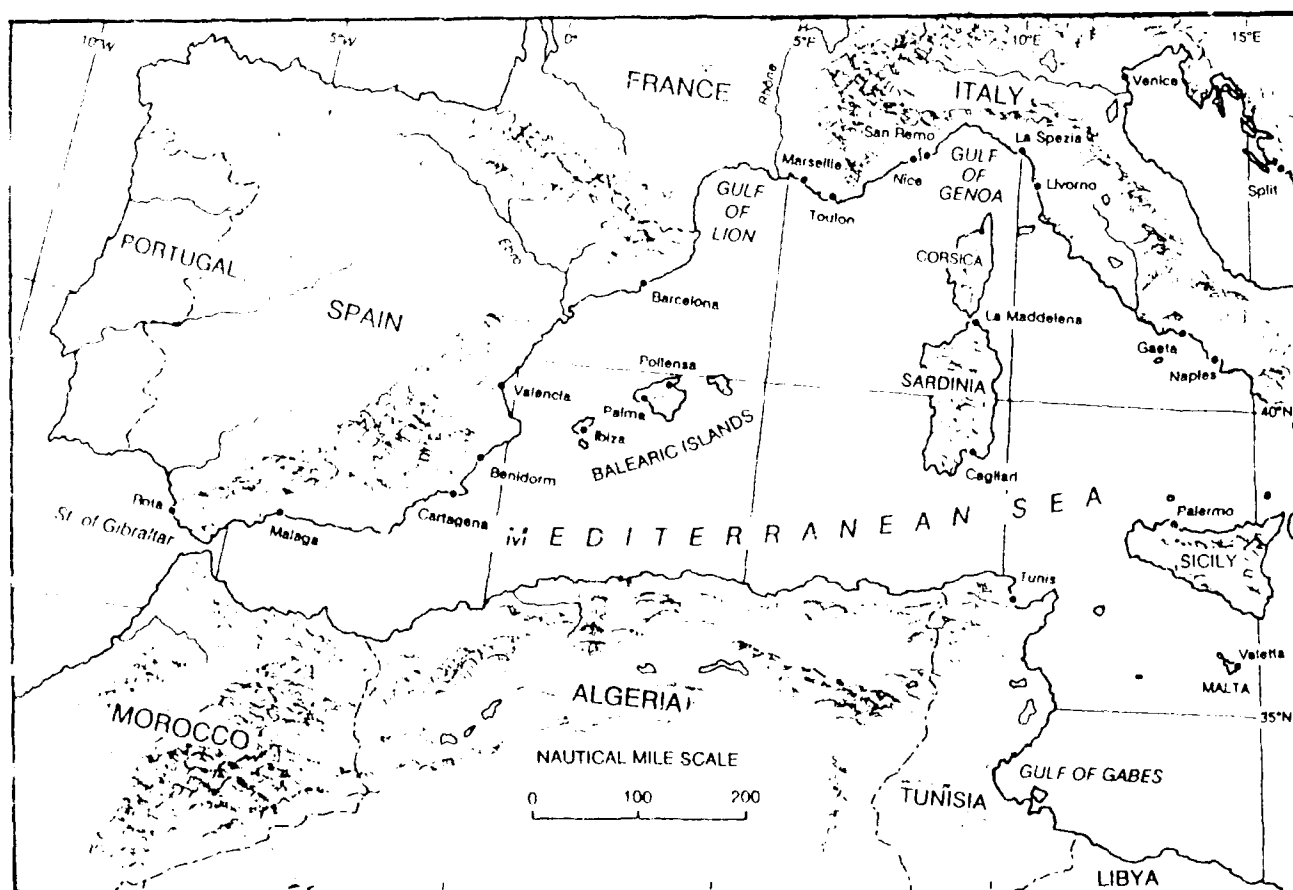


Figure 3-1 Western Mediterranean Sea

The Port of Palma is positioned at the head of the Bay of Palma on the south coast of the southwestern portion of the island (Figure 3-2). The bay is located at the southwest end of an island-wide plain which lies east of a ridge of rugged limestone mountains situated along the west coast of the island. Peaks in the mountains rise to a maximum height of 4,741 ft (1,445 m) (FICEURLANT, 1987). East of the plain is a discontinuous series of low hills which do not exceed 1,800 ft (549 m).

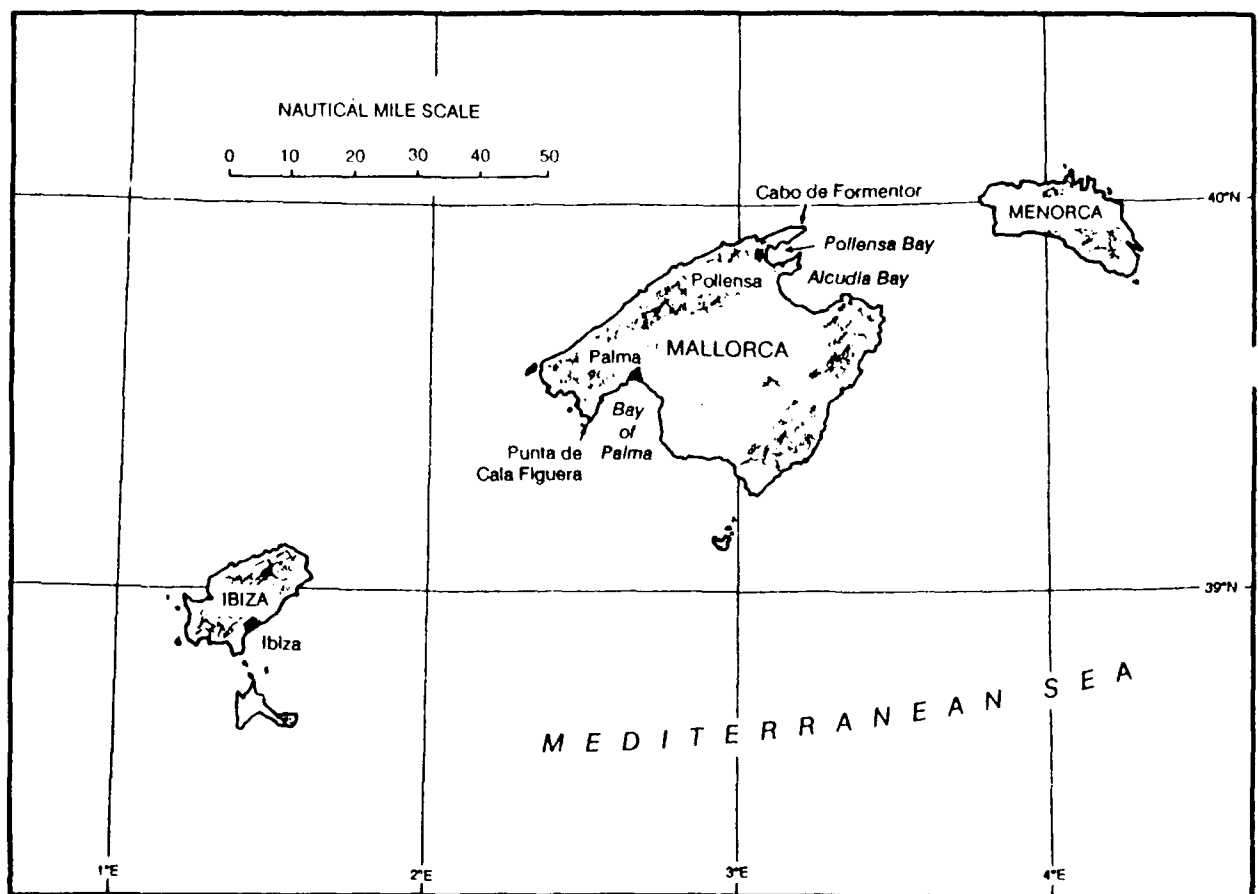


Figure 3-2. Balearic Islands.

The port is medium-sized, and capable of accommodating several ships with drafts to 40 ft (12 m). The inner harbor is spacious and well dredged with ample maneuvering room (FICEURLANT, 1987). It is sheltered on the south and east by breakwaters, and on the west and north by land (Figure 3-3). Large ships, including aircraft carriers, are assigned to an anchorage located on a bearing of 151°, 1,600 yd (1,463 m) from the head of the west breakwater, Dique del Oeste.

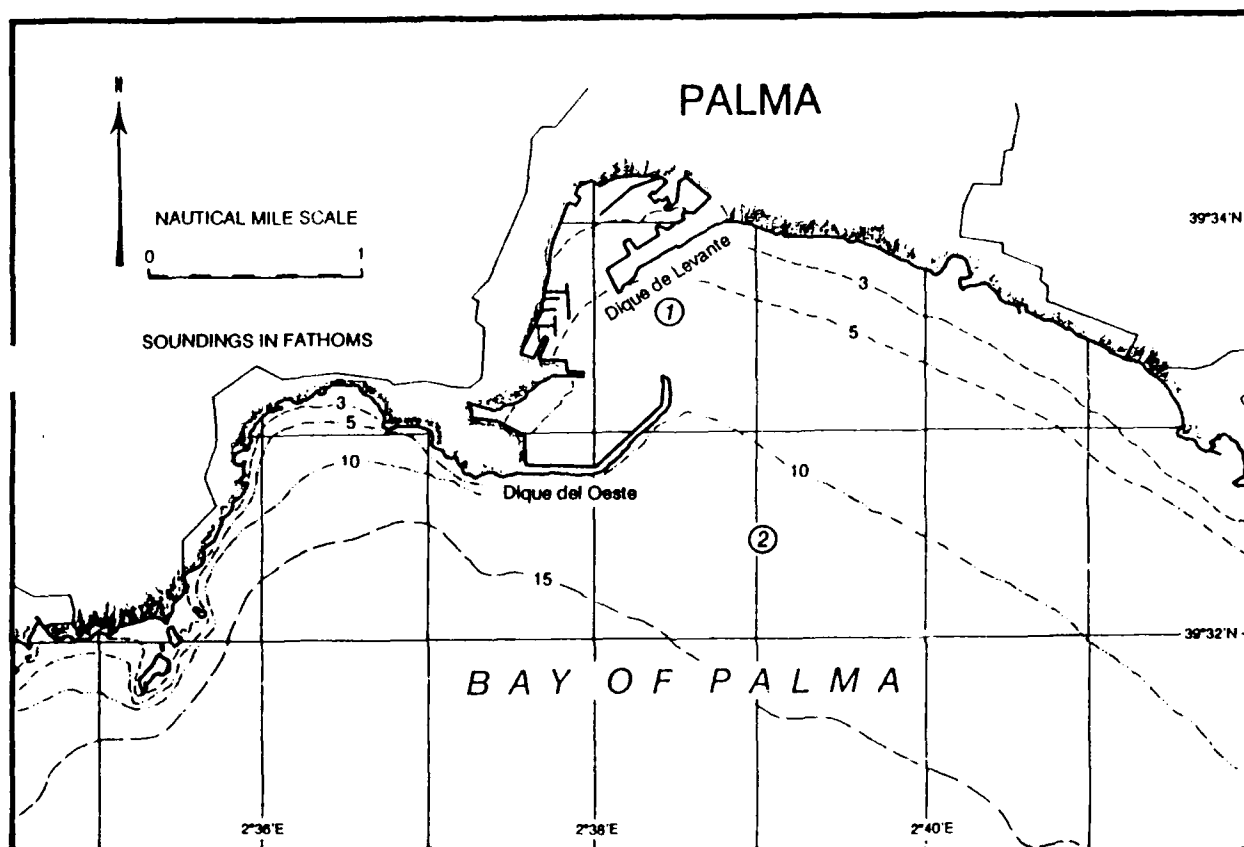


Figure 3-3. Port of Palma de Mallorca.

### 3.2 Qualitative Evaluation of the Port of Palma as a Haven

The inner harbor of the Port of Palma is well protected. According to local mariners, winds and waves do not necessitate protective measures within the harbor. A tall quay wall on Dique del Oeste provides ample shelter for moored vessels.

The anchorage is exposed to some of the conditions from which the inner harbor is sheltered. Southeasterly waves, both sea and swell, of 10 to 13 ft (3 to 4 m) reach the anchorage about 7 days per year. Usually caused by Scirocco winds (locally called Xaloc), the event is difficult to predict. Southwesterly winds can generate waves which reach Punta de Cala Figuera (about 8 n mi southwest of the port) with heights of 10 to 13 ft (3 to 4 m), but the waves diminish somewhat before they reach the anchorage. The anchorage has a good mud and sand bottom, with 90 to 100 fm of chain on a single anchor recommended. Local authorities state that in the past 15 years, no ship has been moved from the anchorage due to bad weather.

### 3.3 Currents and Tides

There are no significant currents in the Bay of Palma and tides are negligible. There is no astronomical tide but a barometric tide exists, with a variation of 6 to 8 inches (15 to 20 cm). High pressure results in a lowering of the water level, while low pressure raises it.

### 3.4 Visibility

Visibility is normally greater than 7 n mi, and only rarely reduces to less than 4 n mi. Haze persists throughout the year. Patchy fog, reducing visibility to near zero, may occur on 2 or 3 days of the winter season,

with January having the highest frequency of occurrence. Near zero visibility due to fog is an early morning phenomenon.

### 3.5 Hazardous Conditions

The inner harbor of the Port of Palma is well protected from hazardous conditions, but the roadstead is exposed to winds and seas from east through southwest. A seasonal summary of the various known environmental hazards that may be encountered in the Port of Palma follows.

#### A. Winter (mid-January through March)

Prevailing winds are northwest clockwise through northeast. The mean wind speed during February and March (tied with November for the highest mean speed) is 5 kt. The remaining months of the year have a 4 kt mean, so the winter winds are only slightly stronger, on average, than the rest of the year. Gale force winds, force 8 (34-40 kt) or greater, have a higher frequency of occurrence during January and February than during the other months of the year, averaging between 2 and 3 events each month.

The rugged topography of the island of Mallorca, and the location of the Port of Palma at the north end of the well-defined Bay of Palma, protects the port from many of the hazardous weather conditions of the region. Consequently, the primary threats to the port are those which come from the south quadrant.

Southeasterly waves, both sea and swell, of 10 to 13 ft (3 to 4 m) reach the port area approximately 7 times per year. The condition is known locally as "Xaloc", but it is more widely known as Scirocco (Reiter, 1975). Scirocco conditions in the western Mediterranean usually result from wind flow in the warm sector of cyclones located north of the area (Brody and Nestor, 1980). The waves can cause considerable motion of ships in the roadstead, but good holding qualities of the bottom preclude any need to weigh anchor and seek better

protection. Because of the protection afforded by its breakwaters, the inner harbor is not adversely affected by the waves.

Southwesterly winds and waves also reach the port area. Broad scale southwesterly flow may precede cold frontal passage (and follow a southeasterly Xaloc event), raising waves in the Mallorca area. Called the Vendaal, the winds are not long lived. They may generate waves of 10 to 13 ft (3 to 4 m) near Punta de Cala Figuera (about 8 n mi southwest of the port), but they diminish somewhat before they reach the Palma roadstead. Because of the good holding quality of the bottom, problems in the anchorage are minimized, and ships can remain at anchor. The southwesterly conditions have little effect on inner harbor operations.

The northwesterly Mistral winds which are common over the Gulf of Lion in late winter and early spring sometimes extend as far southward as Mallorca. Their direction is north to north-northeast when they reach Palma (Meteorological office, Air Ministry, 1962) and they have no effect on port operations. It is during Mistral events that Palma experiences its best visibility.

Easterly winds (Levante) have no effect on port operations, but indicate that cloudy, rainy weather can be expected for 3 days after onset.

Precipitation is common at Palma during the season, with each of the winter months having 5 or 6 days during which 0.04 inch or more of moisture is recorded. Thunderstorms are rare during any season, occurring on an average of less than once per year at the port; however, very heavy northwesterly squalls are sometimes experienced (Hydrographic Department, 1963).

Winter visibility is the worst of the year, with January having an average of 5 days when the visibility decreases to less than 1100 yd. The frequency of occurrence decreases as the season progresses.

Temperatures are moderate during the season. January is the coldest month, with a mean daily maximum

of 57°F (14°C), and mean daily minimum of 44°F (7°C). Wind chill--the cooling effect of temperature combined with wind--is not normally a problem at Palma, but in December 1982, a ship experienced ice pellets, snow, and rain showers with a wind chill of 19°F (-7°C) (FICEURLANT, 1987). Wind chill must be considered on cool and windy winter days. Table 3-1 can be used to determine wind chill for various temperature and wind combinations.

Table 3-1. Wind Chill. The cooling power of the wind expressed as "Equivalent Chill Temperature" (adapted from Kotsch, 1983).

Wind Speed		Cooling Power of Wind expressed as "Equivalent Chill Temperature"									
Knots	MPH	Temperature (°F)									
Calm	Calm	40	35	30	25	20	15	10	5	0	
Equivalent Chill Temperature											
3-6	5	35	30	25	20	15	10	5	0	-5	
7-10	10	30	20	15	10	5	0	-10	-15	-20	
11-15	15	25	15	10	0	-5	-10	-20	-25	-30	
16-19	20	20	10	5	0	-10	-15	-25	-30	-35	
20-23	25	15	10	0	-5	-15	-20	-30	-35	-45	
24-28	30	10	5	0	-10	-20	-25	-30	-40	-50	
29-32	35	10	5	-5	-10	-20	-30	-35	-40	-50	
33-36	40	10	0	-5	-15	-20	-30	-35	-45	-55	

#### B. Spring (April to mid-June)

As is the case over much of the western Mediterranean Sea, the winter weather events--the southeasterly and southwesterly winds and seas--continue through April, but diminish in frequency and intensity as summer approaches. By May, gale force winds are rare. Easterly winds continue to indicate forthcoming cloudy, rainy weather for the following 3 days.

The warmer days of spring result in a sea breeze regime. Although it can occur on warm days during winter, the sea breeze becomes well established and is a more or less daily phenomenon by April. Known locally as the "Embat," the wind usually begins at solar noon, and reaches force 3 to 4 (7-10 to 11-16 kt) during the afternoon, before calming at sunset. Having a southerly direction, the sea breeze can raise a 3 ft (0.9 m) sea in the roadstead. Port operations are not affected.

Monthly precipitation amounts remain essentially constant from January through May. The average number of days when 0.04 inch of rain (or more) is recorded decreases, however, indicating a trend toward shorter periods of heavier, mostly showery type, precipitation. Monthly accumulation decreases significantly in June. Thunderstorm activity, though possible, is uncommon, having a frequency of occurrence of less than once per year. The very heavy northwesterly squalls occasionally experienced during winter may occur early in the season, but are rare by May.

Temperatures warm considerably during the season, reaching a mean maximum of 78°F (26°C) during June, with a mean minimum temperature of 64°F (18°C) for the same month.

#### C. Summer (mid-June through September)

Summertime in Palma is pleasant, with light winds and warm temperatures being the rule. Prevailing wind directions during summer are northeast and southwest. Gale force (34 to 40 kt or greater) winds are rare, and are of short duration. They usually occur when the gradient flow coincides with and reinforces the afternoon sea breeze. A daily sea breeze of force 3 to 4 (7-10 to 11-16 kt) is observed, starting about noon and lasting until sunset. Seas to 3 ft (0.9 m) are routinely raised in the roadstead by the sea breeze, but calm quickly after sunset. A land breeze from the north is generated at night, and lasts until morning. Winds are calm mid to late morning during the transition from land breeze to sea breeze. Precipitation is at its yearly minimum in July and August, but September brings a significant increase in accumulation with an average fall of 2.3 inches recorded.

#### D. Autumn (October to mid-January)

The autumn season brings significant change to Palma. The wind events of winter and early spring begin to occur with increasing regularity, but gale force (34 to 40 kt) winds are rare until November. Easterly winds (Levante) occur with greater frequency as

the season progresses, providing a warning of clouds and rainy conditions for the 3 days following onset. October's precipitation is the highest of the year, with an average of over 3 inches accumulating during the month. The precipitation occurs on more days of the month (7) than during any other month. The very heavy northwesterly squalls which are occasionally experienced in winter are possible by the end of the season. As would be expected, temperatures decrease regularly during the season to the coldest temperatures of the year in January.

### 3.6 Harbor Protection

The inner harbor of the Port of Palma is well protected from all hazardous weather, but the roadstead is exposed and, as discussed below, has limited vulnerability to specific wind and wave conditions.

#### 3.6.1 Wind and Weather

The location of the port on the south coast of Mallorca protects it from hazards created by winds from west-southwest clockwise to east-southeast. North to northeast winds reach the harbor area by passing over the plain which spans the island northeast of the port, but even the strongest of the winds, the Mistral, causes no problems in the harbor.

The port is exposed to winds from southeast through southwest, but the wind alone does little to affect port operations. The inner harbor is essentially unaffected, but small boat runs to/from the anchorage are impacted. When winds are force 5 (17-21 kt) or greater, with minimum swell, ships can maneuver so that boating operations can be conducted in their lee. Such operations are precluded, however, when higher swell is present because the ships must head into the wind and waves and the lee effect is lost.

Hazardous weather (as distinguished from wind and waves) at Palma is limited to the very infrequent thunderstorms which, as discussed in section 3.5, occur on an average of less than once per year.

### 3.6.2 Waves

As discussed in section 3.6.1, the location of the Port of Palma affords good protection from hazardous conditions from west-southwest clockwise to east-southeast. Waves from southeast to southwest can reach the port, but pose only limited problems. Because of its breakwater system, the impact of waves from any direction on the inner harbor is minimal; normal operations continue without interruption.

The roadstead is located outside the protective confines of the breakwaters, and is exposed to waves from southeast to southwest. Although sea and swell can attain heights of 10 to 13 ft (3 to 4 m), ships can remain at anchor. Harbor authorities keep a constant watch on waves in the bay. An automated wave buoy located at 39°24'N 02°39'E (about 9.5 n mi due south of the harbor entrance) transmits wave data to the Port Captain's office.

Table 3-2 provides the shallow water wave conditions at the two designated points when deep water swell enters the harbor.

Example: Use of Table 3-2.

For a deep water wave condition of:  
8 feet, 10 seconds, from 210°

The approximate shallow water wave conditions are:

Point 1: 5-6 feet, 10 seconds, from 160°

Point 2: 7 feet, 10 seconds, from 210°

Table 3-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 3-3 for location of the points).

FORMAT: Shallow Water Direction  
Wave Height Ratio: (Shallow Water/Deep Water)

PALMA POINT 1: (Near Inner Harbor Entrance) 35 ft depth						
Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
150°	150° .3	150° .3	155° .4	160° .4	170° .3	180° .2
180°	155° .3	155° .4	160° .5	160° .7	180° .5	180° .2
210°	185° .4	170° .4	160° .7	170° .6	175° .8	185° .6
240°	190° .2	190° .1	195° .2	195° .2	195° .2	195° .2

PALMA POINT 2: (Fleet Anchorage) 75 ft depth						
Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
150°	170° .8	170° .8	175° .5	175° .4	180° .4	185° .4
180°	180° .8	185° .8	190° .8	190° .7	195° .5	190° .2
210°	210° .9	210° .9	210° .9	210° .9	205° .9	205° .9
240°	210° .8	210° .7	220° .5	225° .7	225° .5	225° .4

Situation-specific shallow water wave conditions resulting from deep water wave propagation are given in Table 3-2 while the seasonal climatology of wave conditions in the harbor resulting from the propagation of deep water waves into the harbor are given in Table 3-3. If the actual or forecast deep water wave conditions are known, the expected conditions at the two specified harbor areas can be determined from Table 3-2. The mean duration of the condition, based on the shallow water wave heights, can be obtained from Table 3-3.

Example: Use of Tables 3-2 and 3-3.

The forecast for wave conditions tomorrow  
(winter case) outside the harbor are:

10 feet, 12 seconds, from 240°

Expected shallow water conditions and duration:

	<u>Point 1</u>	<u>Point 2</u>
Height	2 feet	7 feet
Period	NA	12 seconds
Direction	from 195°	from 225°
Duration	NA	12 hours

Interpretation of the information from Tables 3-2 and 3-3 provides guidance on the local wave conditions expected tomorrow at the various harbor points. The duration values are mean values for the specified height range and season. Knowledge of the current synoptic pattern and forecast/expected duration should be used when available.

Possible applications to small boat operations are selection of the mother ships anchorage point and/or areas of small boat work. The condition duration information provides insight as to how long before a change can be expected. The local wave direction information can be of use in selecting anchorage configuration and related small boat operations, including tending activities.

Table 3-3. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m) by climatological season.

PALMA POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	1	<< 1	<< 1	1
Average Duration (hr)	11	NA	NA	12
Period Max Energy(sec)	10-11	NA	NA	10
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	NA	NA	NA	NA
Average Duration (hr)	NA	NA	NA	NA
Period Max Energy(sec)	NA	NA	NA	NA
PALMA POINT 2:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	9	9	3	10
Average Duration (hr)	12	13	17	10
Period Max Energy(sec)	9-10	9-10	9-10	9-10
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	1	<< 1	<< 1	1
Average Duration (hr)	12	NA	NA	6
Period Max Energy(sec)	11	NA	NA	10

Local wind wave conditions are provided in Table 3-4 for Palma Points 1 and 2. The fetch lengths are specifically for Points 1 and 2. The time to reach the fetch limited height assumes an initial flat ocean. With a pre-existing wave height, the times are shorter.

Table 3-4. Palma. Local wind waves for fetch limited conditions at Points 1 and 2 (based on JONSWAP model).

Points 1 & 2.

Format: height (feet)/period (seconds)  
time (hours) to reach fetch limited height

Direction and\ Fetch \ Length \	Local Wind Speed (kt)						
	14	16	18	24	30	36	42
(n mi)							
SE	<2 ft	<2 ft	<2 ft	2/3	3/3-4	3-4/3-4	4/4
6 n mi				1-2	1-2	1-2	1-2
SW	<2 ft	<2 ft	<2 ft	2-3/3-4	3-4/3-4	3-4/4	4-5/4-5
8 n mi				1-2	1-2	1-2	1-2
S*	2-3/4-5	3/4-5	3-4/5	5/5-6	6/6	7/6	8/6-7
30 n mi	3	4	4	4	3-4	3-4	3

\* 30 n mi is considered the usual fetch length for a sea breeze event.

Example: Small boat wave forecasts for Points 1 & 2  
(based on the assumption that swell is not a limiting condition).

Forecast for Tomorrow:

<u>Time</u>	<u>Wind (Forecast)</u>	<u>Waves (Table 3-4)</u>
prior to 0900 LST	SW 12-15 kt	< 2 ft
0900 to 1800	SW 22-26 kt	2-3 ft
1800 to 2100	SW 11-16 kt	< 2 ft

Interpretation: Assuming that the limiting factor is waves greater than 3 feet, small boat operations would not become marginal unless the windspeed were to increase to 30 kt or more.

Combined wave heights are computed by finding the square root of the sum of the squares of the wind wave and swell heights. For example, if the wind waves were 3 ft and the swell 8 ft the combined height would be about 8.5 ft.

$$\sqrt{3^2 + 8^2} = \sqrt{9 + 64} = \sqrt{73} \approx 8.5$$

Note that the increased height is relatively small. Even if the two wave types were of equal height the combined heights are only 1.4 times the equal height. In cases where one or the other heights are twice that of the other, the combined height will only increase over the larger of the two by 1.12 times (10 ft swell and 5 ft wind wave combined results in 11.2 ft height).

### 3.6.3 Wave Data Uses and Considerations

Local wind waves build up quite rapidly and also decrease rapidly when winds subside. The period and, therefore, length of wind waves is generally short relative to the period and length of waves propagated into the harbor (see Appendix A). The shorter period and length result in wind waves characterized by choppy conditions. When wind waves are superimposed on deep water waves propagated into shallow water, the waves can become quite complex and confused. Under such conditions, when more than one source of waves is influencing a location, tending or joint operations can be hazardous even if the individual wave train heights are not significantly high. Vessels of various lengths may respond with different motions to the diverse wave lengths present. The information on wave periods, provided in the previous tables, should be considered when forecasts are made for joint operations of various length vessels.

### 3.7 Protective and Mitigating Measures

#### 3.7.1 Sortie/Remain in Port

Due to the excellent protection provided by the breakwaters, ships moored in the inner harbor should not find it necessary to sortie. Doubling of lines may be required to prevent vessels from shifting at their moorings in strong winds.

#### 3.7.2 Moving to New Anchorage

Although the anchorage is exposed to waves from the south quadrant, and boating to/from the anchorage and inner harbor may be hazardous, moving to a different anchorage because of heavy weather should not be required. Local authorities state that no such movement has been necessary in 15 years. If conditions warrant a move, however, moving to Pollensa Bay or Alcudia Bay on the northeast side of Mallorca would provide protection from waves from the south quadrant; however, southerly winds funnel across Mallorca and into Pollensa Bay, reaching the anchorage as southwesterly force 5 to 6 (17-21 to 22-27 kt) and can cause ships to drag anchor toward deeper water.

#### 3.7.3 Scheduling

Because the Port of Palma is not subject to many hazardous weather events, scheduling problems are essentially limited to avoiding periods of strong winds and associated waves. Those conditions occur with greatest intensity and frequency during late autumn, winter, and early spring seasons. Even during the months of greatest threat, the probability of encountering heavy weather at the port is slight.

On warm days, if calm or near calm wind conditions are required for an operation, scheduling the

evolution prior to late morning or in the evening after sunset will avoid the strongest sea breezes.

### 3.8 Local Indicators of Hazardous Weather Conditions

Hazardous weather at the Port of Palma is limited to high winds and/or waves from southeast clockwise to southwest. Other conditions, such as Mistral winds and the sea breeze, are more bothersome than hazardous. The following guidelines have been extracted from a variety of sources, including on-site discussions with harbor personnel. They are intended to assist the meteorologist in forecasting hazardous (or in some cases, just bothersome) weather events.

#### Southerly winds and waves

Southerly winds raise the level of the water in the harbor, and northerly winds lower it. When the water level rises, a southerly wind can be expected in 5 to 6 hours. NOTE: Because the water level also varies with barometric pressure changes, this guideline must be used with caution by visiting mariners.

Southerly winds can raise waves (sea and swell) of 10 to 13 ft (3 to 4 m). Southerly swell often precedes the wind that raised it (Hydrographic Department, 1963).

Sustained south to southwesterly winds of 20 kt or greater can cause boating difficulties at the Palma large ship anchorage. Brief periods (2-4 hours) of 20 kt southwesterly winds can cause 5 ft seas (Brody and Nestor, 1980).

#### Northerly winds

When the water level in the harbor lowers, a northerly wind can be expected in 5 to 6 hours. NOTE: Because the water level also varies with diurnal barometric pressure changes, this guideline must be used with caution by visiting mariners. Even though the winds may be strong and of Mistral origin, port operations are not affected.

Northwesterly winds result in very good visibilities at Palma.

#### Sea and land breeze

The local sea breeze, called "Embat," is consistent, starting at solar noon on warm days, and reaches force 3 to 4 (7-10 to 11-16 kt) by late afternoon. It has a southerly direction, and can generate 3 ft (0.9 m) seas at the anchorage. The sea breeze normally calms at sunset, with the seas calming shortly thereafter. The summer open ocean wind is from the south to southwest about 30% of the time with an average speed of 8 kt. When this is reinforced by the sea breeze, wind waves of 3 to 5 ft will occur at this anchorage area. This condition can be used to demonstrate the results of combining the local wind waves (sea breeze generated) with the synoptic scale wave conditions. With a strong sea breeze of about 16 kt, Table 3-4 indicates waves of 3 ft after 4 hours duration. A synoptic flow of 10 to 12 kt from the south would generate about a 2 ft significant wave after about four hours over at least a 30 n mi fetch (JONSWAP model, see Appendix A). These two wave trains would combine as:

$$\sqrt{3^2 + 2^2} = \sqrt{9 + 4} = \sqrt{13} = 3.6 \text{ ft}$$

With a significant wave of 3.6 ft, the local information indicating 3 to 5 ft under a reinforced sea breeze regime is a reasonable expectation and/or observation.

A mild land breeze occurs at night and early morning. A calm period results in mid to late morning during the transition from land breeze to sea breeze.

### 3.9 Summary of Problems, Actions, and Indicators

Table 3-5 is intended to provide easy-to-use seasonal references for meteorologists on ships using the Port of Palma. Table 2-1 (Section 2) summarizes Table 3-5 and is intended primarily for use by ship captains.

Table 3-5. Potential problem situations at Po

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/E
<p>1. <u>Moored-Inner harbor.</u></p> <p>Winter Spring Summer Autumn</p>	<p>There are no weather related hazards that significantly effect the inner harbor at the Port of Palma. Vessels moored therein are sheltered from S'ly waves which enter the Bay of Palma, and S'ly winds have no significant impact. Mistral winds reach the Port from W to NNE, but have no significant effect. E'ly winds (Levante) also have no effect other than foretelling of cloudy and rainy weather that will last for the 3 days following onset.</p>	<p><u>NONE</u></p>
<p>2. <u>Anchored.</u></p> <p>Winter Spring Summer Autumn</p> <p>Least likely in</p> <p>Winter Spring Summer Autumn</p> <p>Least likely in</p>	<p>a. <u>SE'ly winds/waves</u> - Caused by synoptic scale SE flow, likely a Scirocco (known locally as Xaloc). Waves of 10 to 13 ft (3 to 4 m) may reach the anchorage. Commonly brings very warm temperatures, and may be accompanied by low clouds.</p> <p>b. <u>SW'ly winds/waves</u> - Caused by synoptic scale SW flow, most likely pre-frontal Vendaval winds. Waves of 10 to 13 ft (3 to 4 m) may reach Punta de Cala Figuera but diminish somewhat by the time they reach the anchorage. May be accompanied by rain.</p>	<p>a. Winds and waves will reach the anchorage, but remain on a single anchor with 90 to 100 fm of anchorage better protected from waves is deemed Pollensa Bay or Alcudia Bay on the northeast side recommended. But S'ly winds funnel to Pollensa anchorage as SW force 5 to 6 (17-21 to 22-27 kt) anchor northeast toward deeper water. Alcudia dragging before hazards are encountered.</p> <p>b. Winds and waves will reach the anchorage, but remain on a single anchor with 90 to 100 fm of anchorage better protected from waves is deemed Alcudia Bay on the northeast side of Mallorca. S'ly winds funnel to Pollensa Bay and may reach the 6 (17-21 to 22-27 kt). May cause ships to drag deeper water. Alcudia Bay provides more room if are encountered.</p>
<p>3. <u>Arriving/departing.</u></p> <p>Winter Spring Summer Autumn</p> <p>Least likely in</p> <p>Winter Spring Summer Autumn</p> <p>Least likely in</p>	<p>a. <u>SE'ly winds/waves</u> - Caused by synoptic scale SE flow, likely a Scirocco (known locally as Xaloc). Waves of 10 to 13 ft (3 to 4 m) may reach the anchorage. Commonly brings very warm temperatures, and may be accompanied by low clouds.</p> <p>b. <u>SW'ly winds/waves</u> - Caused by synoptic scale SW flow, most likely pre-frontal Vendaval winds. Waves of 10 to 13 ft (3 to 4 m) may reach Punta de Cala Figuera but diminish somewhat by the time they reach the anchorage. May be accompanied by rain.</p>	<p>a. Inbound and outbound vessels should be able inner harbor without difficulty since adequate available inside the breakwaters. Ships arriving experience no significant difficulty since hold sand bottom. If conditions at the anchorage are protected anchorage can be found at Pollensa Bay northeast side of Mallorca. Small boat operation harbor and the anchorage may be hazardous.</p> <p>b. Inbound and outbound vessels should be able inner harbor without difficulty since adequate available inside the breakwaters. Ships arriving experience no significant difficulty since hold sand bottom. If conditions at the anchorage are protected anchorage can be found at Pollensa Bay northeast side of Mallorca. Small boat operation harbor and the anchorage may be hazardous.</p>

# ons at Port of Palma, Mallorca - ALL SEASONS

I TIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
<p>the anchorage, but ships should be able to to 100 fm of chain. If moving to an aves is deemed necessary, moving to e northeast side of Mallorca is el to Pollensa Bay and may reach the 21 to 22-27 kt). May cause ships to drag eer. Alcudia Bay provides more room for nterfered.</p> <p>the anchorage, but ships should be able to to 100 fm of chain. If moving to an aves is deemed necessary, Pollensa Bay or of Mallorca are recommended. But S'ly ay reach the anchorage as SW force 5 to ships to drag anchor northeast toward es more room for dragging before hazards</p> <p>should be able to proceed to/from the nce adequate maneuvering room is Ships arriving at the anchorage should ity since holding is good on a mud and e anchorage are deemed hazardous, a more at Pollensa Bay or Alcudia Bay on the l boat operations to/from the inner azardous.</p> <p>should be able to proceed to/from the nce adequate maneuvering room is Ships arriving at the anchorage should ity since holding is good on a mud and Alc anchorage are deemed hazardous, a more at Pollensa Bay or Alcudia Bay on the l boat operations to/from the inner azardous.</p>	<p>NONE</p> <p>a. The most likely cause of SE'ly winds and waves at Palma is a synoptic scale event, such as Scirocco (Xaloc) winds in the warm sector of cyclones passing north of Mallorca. Conditions will abate gradually as the associated cyclone moves east. Arrival of a southerly swell may precede the winds that raised it. Swell waves will diminish gradually after the wind field over the fetch area weakens or moves. With time, the swell waves will diminish in height and have shorter periods. The water level in the harbor varies with wind direction: When the water level rises, a southerly wind can be expected in 5 to 6 hours. NOTE: This guideline must be used with caution because the water level also varies with barometric pressure changes.</p> <p>b. SW'ly winds/waves (Vendaval) will precede cold fronts moving east across Iberian Peninsula. The winds should normally be of relatively short duration at Palma, but SW swell may persist after front has passed and winds have veered westward. The swell waves will gradually diminish in height and period with time. The water level in the harbor varies with wind direction: When the water level rises, a southerly wind can be expected in 5 to 6 hours. NOTE: This guideline must be used with caution because the water level also varies with barometric pressure changes.</p> <p>a. The most likely cause of SE'ly winds and waves at Palma is a synoptic scale event, such as Scirocco (Xaloc) winds in the warm sector of cyclones passing north of Mallorca. Conditions will abate gradually as the associated cyclone moves east. Arrival of a southerly swell may precede the winds that raised it. Swell waves will diminish gradually after the wind field over the fetch area weakens or moves. With time, the swell waves will diminish in height and have shorter periods. The water level in the harbor varies with wind direction: When the water level rises, a southerly wind can be expected in 5 to 6 hours. NOTE: This guideline must be used with caution because the water level also varies with barometric pressure changes.</p> <p>b. SW'ly winds/waves (Vendaval) will precede cold fronts moving east across Iberian Peninsula. The winds should normally be of relatively short duration at Palma, but SW swell may persist after front has passed and winds have veered westward. The swell waves will gradually diminish in height and period with time. The water level in the harbor varies with wind direction: When the water level rises, a southerly wind can be expected in 5 to 6 hours. NOTE: This guideline must be used with caution because the water level also varies with barometric pressure changes.</p>

Table 3-5. (Con

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EV
<p>4. <u>Small boats.</u></p> <p>Least likely in Winter Spring Summer Autumn</p> <p>Least likely in Winter Spring Summer Autumn</p> <p>Least likely in Winter Spring Summer Autumn</p>	<p>a. <u>SE'ly winds/waves</u> - Caused by synoptic scale SE flow, likely a Scirocco (known locally as Xaloc). Waves of 10 to 13 ft (3 to 4 m) may reach the anchorage. Commonly brings very warm temperatures, and may be accompanied by low clouds.</p> <p>b. <u>SW'ly winds/waves</u> - Caused by synoptic scale SW flow, most likely pre-frontal Vendaval winds. Waves of 10 to 13 ft (3 to 4 m) may reach Punta de Cala Figuera but diminish somewhat by the time they reach the anchorage. May be accompanied by rain. Sustained S to SW winds of 20 kt or greater can cause boating difficulties at the aircraft carrier anchorage. Brief periods of 20 kt SW winds can cause 5 ft seas.</p> <p>c. <u>Sea breeze</u> - Locally called "Eubat," it is a common occurrence at Palma. Consistently occurs on warm days during spring, summer, and autumn, and may occur during winter. Commencing near solar noon, the S'ly wind may reach force 3 to 4 (7-10 to 11-16 kt) by mid to late afternoon. May raise 3 ft (about 1 m) seas at the anchorage. Usually calms at sunset.</p>	<p>a. Small boats should experience no significant the inner harbor due to the protection afforded. Operations outside the breakwaters will be exposed. Curtailment of runs to/from the anchorage may be periods of relatively strong wind--force 5 (17-21 kt) or greater. Minimal swell, ships can maneuver such that boats conducted on their lee side with little problem present, however, ships must head into the swell operations hazardous.</p> <p>b. Small boats should experience no significant the inner harbor due to the protection afforded. Operations outside the breakwaters will be exposed. Curtailment of runs to/from the anchorage may be</p> <p>c. Small boat operations, both in the inner harbor anchorage, should not be a major problem. By the sea breeze is strongest and has raised a 3 ft anchorage, runs to/from the anchorage and inner choppy wave conditions. Unless other waves are operations should not be necessary.</p>

CAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
<p>Since no significant difficulty operating in protection afforded by the breakwaters. Vessels will be exposed to winds and waves; anchorage may be necessary. During wind--force 5 (17-21 kt) or greater--with a swell such that boating operations can be a little problem. When higher swell is added into the swell, making small boat</p> <p>Since no significant difficulty operating in protection afforded by the breakwaters. Vessels will be exposed to winds and waves; anchorage may be necessary.</p> <p>in the inner harbor as well as at the outer problem. By mid to late afternoon, when swell has raised a 3 ft (about 1 m) sea at the anchorage and inner harbor may encounter other waves are present, curtailment of activity.</p>	<p>a. The most likely cause of SE'ly winds and waves at Palma is a synoptic scale event, such as Scirocco (Xaloc) winds in the warm sector of cyclones passing north of Mallorca. Conditions will abate gradually as the associated cyclone moves east. Arrival of a southerly swell may precede the winds that raised it. Swell waves will diminish gradually after the wind field over the fetch area weakens or moves. With time, the swell waves will diminish in height and have shorter periods. The water level in the harbor varies with wind direction: When the water level rises, a southerly wind can be expected in 5 to 6 hours. NOTE: This guideline must be used with caution because the water level also varies with barometric pressure changes.</p> <p>b. SW'ly winds/waves (Vendaval) will precede cold fronts moving east across Iberian Peninsula. The winds should normally be of relatively short duration at Palma, but SW swell may persist after front has passed and winds have veered westward. The swell waves will gradually diminish in height and period with time. The water level in the harbor varies with wind direction: When the water level rises, a southerly wind can be expected in 5 to 6 hours. NOTE: This guideline must be used with caution because the water level also varies with barometric pressure changes.</p> <p>c. A sea breeze will occur on most warm days, with the strongest winds, force 3 to 4 (7-10 to 11-16 kt), reached by mid to late afternoon. Least likely during November, December, January and February, but can occur during any month.</p>

## REFERENCES

Brody, L.R. and M.J.R. Nestor, 1980: Regional Forecasting Aids for the Mediterranean Basin, NAVENVPREDRSCHFAC Technical Report TR 80-10. Naval Environmental Prediction Research Facility, Monterey, California 93941.

FICEURLANT, 1987: Port Directory for Palma (1985), Balearic Islands. Fleet Intelligence Center Europe and Atlantic, Norfolk, Virginia.

Hydrographic Department, 1963: Mediterranean Pilot, Volume I. Published by the Hydrographic Department, under the authority of the Lords Commissioners of the Admiralty, London.

Kotsch, W.J., 1983: Weather for the Mariner, Third Edition. Naval Institute Press, Annapolis, Maryland.

Reiter, E.R., 1975: Handbook for Forecasters in the Mediterranean. Environmental Prediction Research Facility, Naval Postgraduate School, Monterey, California 93940

## PORT VISIT INFORMATION

MAY 1987. NEPRF meteorologists D. Perryman and R. Miller met with the Port Captain and Chief Pilot to obtain much of the information used in this port evaluation.

## APPENDIX A

### General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always

present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

#### A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN- BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period ( $f = 1/T$ ) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

## A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and a given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where  $v$  is the wind speed in knots.

$$f_{\max} = \frac{2.476}{v} \quad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining

frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \quad (1.2)$$

Where  $v$  is wind speed in knots and  $T$  is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41 \bar{T}^2 \quad (1.3)$$

Where  $\bar{L}$  is average wave length in feet and  $\bar{T}$  is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67"L" \quad (1.4)$$

where " $L$ " =  $5.12T^2$ , the wave length for the classic sine wave.

### A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing

lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAF Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) (hrs)		Sig Wave (H1/3) Period/Height (sec) (ft)		Wave Length (ft) <sup>1,2</sup>	
					Developing/Fully /Arisen	
					L X (.5)	/L X (.67)
10	28 /	4	4 /	2	41 /	55
15	55 /	6	6 /	4	92 /	123
20	110 /	8	8 /	8	164 /	220
25	160 /	11	9 /	12	208 /	278
30	210 /	13	11 /	16	310 /	415
35	310 /	15	13 /	22	433 /	580
40	410 /	17	15 /	30	576 /	772

NOTES:

<sup>1</sup> Depths throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

<sup>2</sup> For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ( $L = 5.12T^2$ ). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell their wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

#### A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

- 1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.
- 2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.
- 3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

Format: height (feet)/period (seconds)  
duration required (hours)

Fetch \ Wind Speed (kt)					
Length \	18	24	30	36	42
(n mi)					
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7 <sup>1</sup> 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

<sup>1</sup> 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

#### WIND FORECAST OR CONDITION

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

#### SEA FORECAST OR CONDITION

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

## A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

## A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water

conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

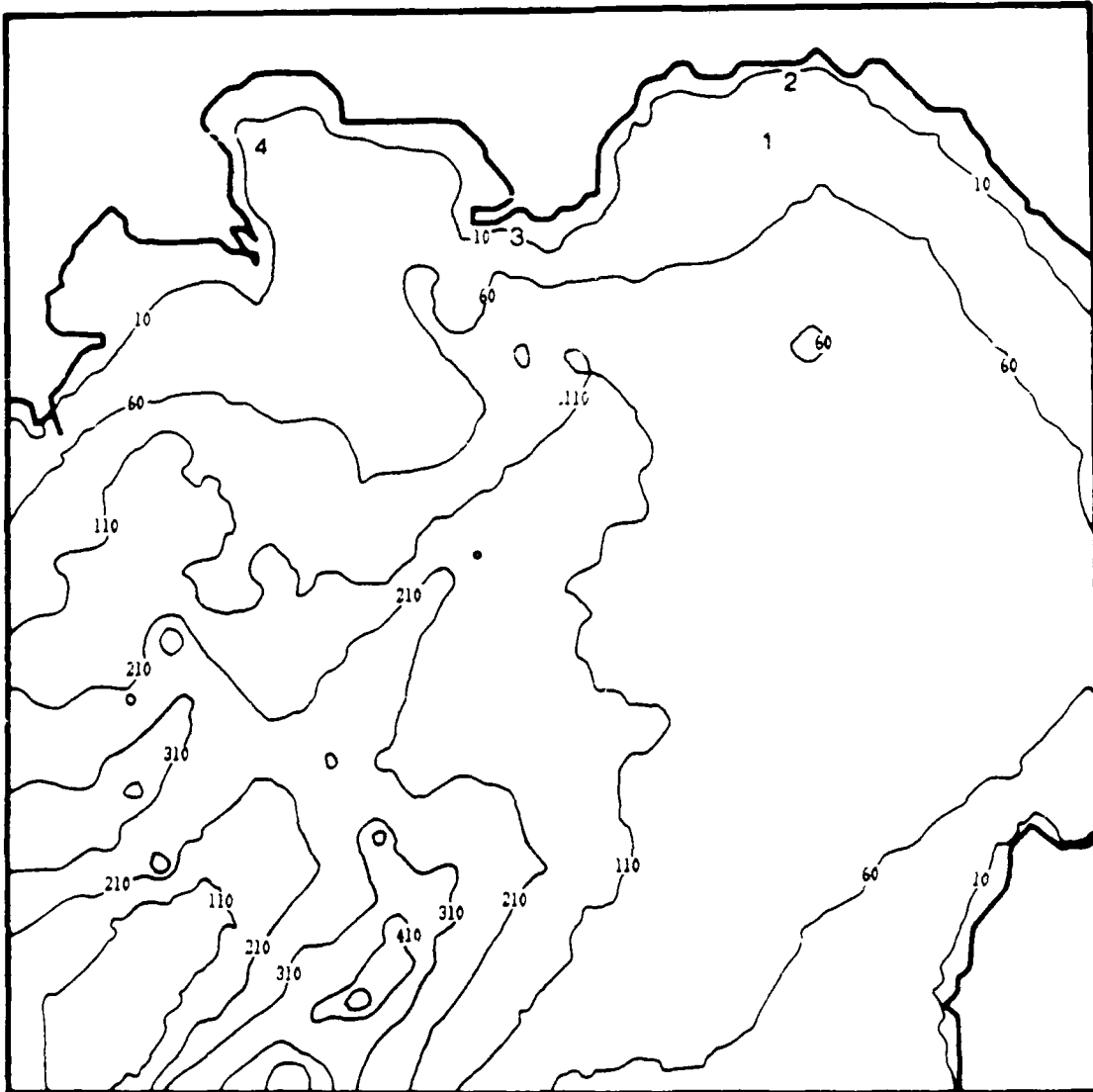


Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathoms to 110 fathoms, and at 100 fathom intervals thereafter. The larger size numbers identify specific anchorage areas addressed in the harbor study.

## REFERENCES

Hasselmann, K. D., D. B. Ross, P. Muller, and W. Sell, 1976: A parametric wave prediction model. J. Physical Oceanography, Vol. 6, pp. 208-228.

Neumann, G., and W. J. Pierson Jr., 1966: Principles of Physical Oceanography. Prentice-Hall, Englewood Cliffs.

Pierson, W. J. Jr., G. Neumann, and R. W. James, 1955: Practical Methods for Observing and Forecasting Ocean Waves, H. O. Pub. No. 603.

Thornton, E. B., 1986: Unpublished lecture notes for OC 3610, Waves and Surf Forecasting. Naval Postgraduate School, Monterey, CA.

U. S. Naval Oceanography Command, 1986: Vol. II of the U. S. Naval Oceanography Command Numerical Environmental Products Manual.

## DISTRIBUTION LIST

### SNDL

21A1	CINCLANTFLT
21A3	CINCUSNAVEUR
22A1	COMSECONDFLT
22A3	COMSIXTHFLT
23B3	Special Force Commander EUR
24A1	Naval Air Force Commander LANT
24D1	Surface Force Commander LANT
24E	Mine Warfare Command
24G1	Submarine Force Commander LANT
26QQ1	Special Warfare Group LANT
28A1	Carrier Group LANT (2)
28B1	Cruiser-Destroyer Group LANT (2)
28D1	Destroyer Squadron LANT (2)
28J1	Service Group and Squadron LANT (2)
28K1	Submarine Group and Squadron LANT
28L1	Amphibious Squadron LANT (2)
29A1	Guided Missile Cruiser LANT
29B1	Aircraft Carrier LANT
29D1	Destroyer LANT (DD 931/945 Class)
29E1	Destroyer LANT (DD 963 Class)
29F1	Guided Missile Destroyer LANT
29G1	Guided Missile Frigate (LANT)
29I1	Frigate LANT (FF 1098)
29J1	Frigate LANT (FF 1040/1051 Class)
29K1	Frigate LANT (FF 1052/1077 Class)
29L1	Frigate LANT (FF 1078/1097 Class)
29N1	Submarine LANT (SSN)
29Q	Submarine LANT SSBN
29R1	Battleship Lant (2)
29AA1	Guided Missile Frigate LANT (FFG 7)
29BB1	Guided Missile Destroyer (DDG 993)
31A1	Amphibious Command Ship LANT (2)
31B1	Amphibious Cargo Ship LANT
31G1	Amphibious Transport Ship LANT
31H1	Amphibious Assault Ship LANT (2)
31I1	Dock Landing Ship LANT
31J1	Dock Landing Ship LANT
31M1	Tank Landing Ship LANT
32A1	Destroyer Tender LANT
32C1	Ammunition Ship LANT
32G1	Combat Store Ship LANT
32H1	Fast Combat Support Ship LANT
32N1	Oiler LANT
32Q1	Replenishment Oiler LANT
32S1	Repair Ship LANT
32X1	Salvage Ship LANT
32DD1	Submarine Tender LANT
32EE1	Submarine Rescue Ship LANT
32KK	Miscellaneous Command Ship
32QQ1	Salvage and Rescue Ship LANT
32TT	Auxiliary Aircraft Landing Training Ship

42N1 Air Anti-Submarine Squadron VS LANT  
 42P1 Patrol Wing and Squadron LANT  
 42BB1 Helicopter Anti-Submarine Squadron HS LANT  
 42CC1 Helicopter Anti-Submarine Squadron Light HSL LANT  
 C40 Monterey, Naples, Sigonella and Souda Bay only  
 FD2 Oceanographic Office - COMNAVOCEANCOM  
 FD3 Fleet Numerical Oceanography Center - FNOC  
 FD4 Oceanography Center - NAVEASTOCEANCEN  
 FD5 Oceanography Command Center - COMNAVOCEANCOM

copy to:

21A2 CINCPACFLT  
 22A2 Fleet Commander PAC  
 24F Logistics Command  
 24H1 Fleet Training Command LANT  
 28A2 Carrier Group PAC (2)  
 29B2 Aircraft Carrier PAC (2)  
 29R2 Battleships PAC (2)  
 31A2 Amphibious Command Ship PAC (2)  
 31H2 Amphibious Assault Ship PAC (2)  
 FA2 Fleet Intelligence Center  
 FC14 Air Station NAVEUR  
 FD1 Oceanography Command  
 USDAO France, Israel, Italy and Spain

Stocked:

NAVPUBFORMCEN (50 copies)

NAVENVPREDRSCHFAC SUPPLEMENTARY DISTRIBUTION

COMMANDING GENERAL (G4)  
FLEET MARINE FORCE, ATLANTIC  
ATTN: NSAP SCIENCE ADVISOR  
NORFOLK, VA 23511

USCINCLANT  
NAVAL BASE  
NORFOLK, VA 23511

COMMANDER IN CHIEF  
U.S. CENTRAL COMMAND  
MACDILL AFB, FL 33608

USCINCENT  
ATTN: WEATHER DIV. (CCJ3-W)  
MACDILL AFB, FL 33608-7001

ASST. FOR ENV. SCIENCES  
ASST. SEC. OF THE NAVY (R&D)  
ROOM SE731, THE PENTAGON  
WASHINGTON, DC 20350

CHIEF OF NAVAL RESEARCH (2)  
LIBRARY SERVICES, CODE 784  
BALLSTON TOWER #1  
800 QUINCY ST.  
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL RESEARCH  
CODE 1122AT, ATMOS. SCIENCES  
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL RESEARCH  
ENV. SCI. PROGRAM, CODE 112  
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL RESEARCH  
ATTN: PROGRAM MANAGER, 1122CS  
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL RESEARCH  
ATTN: HEAD, OCEAN SCIENCES DIV  
CODE 1122  
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL RESEARCH  
CODE 1122 PO, PHYSICAL OCEANO.  
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL RESEARCH  
CODE 1122 MM, MARINE METEO.  
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL TECHNOLOGY  
ONR (CODE 22)  
800 N. QUINCY ST.  
ARLINGTON, VA 22217-5000

CHIEF OF NAVAL OPERATIONS  
(OP-006)  
U.S. NAVAL OBSERVATORY  
WASHINGTON, DC 20390

CHIEF OF NAVAL OPERATIONS  
NAVY DEPT., OP-622C  
WASHINGTON, DC 20350

CHIEF OF NAVAL OPERATIONS  
NAVY DEPT. OP-986G  
WASHINGTON, DC 20350

CHIEF OF NAVAL OPERATIONS  
U.S. NAVAL OBSERVATORY  
DR. RECHNITZER, OP-952F  
34TH & MASS AVE.  
WASHINGTON, DC 20390

CHIEF OF NAVAL OPERATIONS  
OP-952D  
U.S. NAVAL OBSERVATORY  
WASHINGTON, DC 20390

CHIEF OF NAVAL OPERATIONS  
OP-953  
NAVY DEPARTMENT  
WASHINGTON, DC 20350

COMMANDANT OF THE MARINE CORPS  
HQ, U.S. MARINE CORPS  
WASHINGTON, DC 20380

DIRECTOR  
NATIONAL SECURITY AGENCY  
ATTN: LIBRARY (2C029)  
FT. MEADE, MD 20755

OJCS/J3/ESD  
THE PENTAGON, ROOM 28887  
WASHINGTON, DC 20301-5000

OFFICER IN CHARGE  
NAVOCEANCOMDET  
NAVAL STATION  
CHARLESTON, SC 29408-6475

OFFICER IN CHARGE  
U.S. NAVOCEANCOMDET  
BOX 16  
FPO NEW YORK 09593-5000

OFFICER IN CHARGE  
NAVOCEANCOMDET  
NAVAL EDUCATION & TRNG CENTER  
NEWPORT, RI 02841-5000

OFFICER IN CHARGE  
U.S. NAVOCEANCOMDET  
APO NEW YORK 09406-5000

COMMANDING OFFICER  
NAVAL RESEARCH LAB  
ATTN: LIBRARY, CODE 2620  
WASHINGTON, DC 20390

OFFICE OF NAVAL RESEARCH  
SCRIPPS INSTITUTION OF  
OCEANOGRAPHY  
LA JOLLA, CA 92037

COMMANDING OFFICER  
NAVAL OCEAN RSCH & DEV ACT  
NSTL, MS 39529-5004

COMMANDING OFFICER  
FLEET INTELLIGENCE CENTER  
(EURCPE & ATLANTIC)  
NORFOLK, VA 23511

COMMANDER  
NAVAL OCEANOGRAPHY COMMAND  
NSTL, MS 39529-5000

COMNAVOCEANCOM  
ATTN: CODE N5  
NSTL, MS 39529-5000

SUPERINTENDENT  
LIBRARY REPORTS  
U.S. NAVAL ACADEMY  
ANNAPOLIS, MD 21402

CHAIRMAN  
OCEANOGRAPHY DEPT.  
U.S. NAVAL ACADEMY  
ANNAPOLIS, MD 21402

DIRECTOR OF RESEARCH  
U.S. NAVAL ACADEMY  
ANNAPOLIS, MD 21402

NAVAL POSTGRADUATE SCHOOL  
OCEANOGRAPHY DEPT.  
MONTEREY, CA 93943-5000

LIBRARY  
NAVAL POSTGRADUATE SCHOOL  
MONTEREY, CA 93943-5002

PRESIDENT  
NAVAL WAR COLLEGE  
GEOPHYS. OFFICER, NAVOPS DEPT.  
NEWPORT, RI 02841

COMMANDER  
NAVAL SAFETY CENTER  
NAVAL AIR STATION  
NORFOLK, VA 23511

COMSPAWARSSYSCOM  
ATTN: CAPT. R. PLANTE  
CODE 3213, NAVY DEPT.  
WASHINGTON, DC 20363-5100

COMMANDER, D.W. TAYLOR NAVAL  
SHIP RSCH. & DEV. CENTER  
SURFACE SHIP DYNAMICS BRANCH  
ATTN: S. BALES  
BETHESDA, MD 20084-5000

COMMANDER  
NAVSURFWEACEN, CODE R42  
DR. B. KATZ, WHITE OAKS LAB  
SILVER SPRING, MD 20903-5000

DIRECTOR  
NAVSURFWEACEN, WHITE OAKS  
NAVY SCIENCE ASSIST. PROGRAM  
SILVER SPRING, MD 20903-5000

COMMANDING GENERAL  
FLEET MARINE FORCE, LANT (G4)  
ATTN: NSAP SCIENCE ADVISOR  
NORFOLK, VA 23511

USAFETAC/TS  
SCOTT AFB, IL 62225

3350TH TECH. TRNG GROUP  
TTGU/2/STOP 623  
CHANUTE AFB, IL 61868

OFFICER IN CHARGE  
SERVICE SCHOOL COMMAND  
DET. CHANUTE/STOP 62  
CHANUTE AFB, IL 61868

COMMANDING OFFICER  
U.S. ARMY RESEARCH OFFICE  
ATTN: GEOPHYSICS DIV.  
P.O. BOX 12211  
RESEARCH TRIANGLE PARK, NC  
27709

COMMANDER  
COASTAL ENGINEERING RSCH CEN  
KINGMAN BLDG.  
FT. BELVOIR, VA 22060

DIRECTOR  
LIBRARY, TECH. INFO. CEN.  
ARMY ENG. WATERWAYS STN.  
VICKSBURG, MS 39180

DIRECTOR (12)  
DEFENSE TECH. INFORMATION  
CENTER, CAMERON STATION  
ALEXANDRIA, VA 22314

DIRECTOR, ENV. & LIFE SCI.  
OFFICE OF UNDERSECRETARY OF  
DEFENSE FOR RSCH & ENG E&LS  
RM. 3D129, THE PENTAGON  
WASHINGTON, DC 20505

CENTRAL INTELLIGENCE AGENCY  
ATTN: OCR STANDARD DIST.  
WASHINGTON, DC 20505

DIRECTOR, TECH. INFORMATION  
DEFENSE ADV. RSCH PROJECTS  
1400 WILSON BLVD.  
ARLINGTON, VA 22209

COMMANDANT  
DEFENSE LOGISTICS STUDIES  
INFORMATION EXCHANGE  
ARMY LOGISTICS MANAGEMENT  
CENTER  
FORT LEE, VA 23801

COMMANDANT  
U.S. COAST GUARD  
WASHINGTON, DC 20226

CHIEF, MARINE SCI. SECTION  
U.S. COAST GUARD ACADEMY  
NEW LONDON, CT 06320

COMMANDING OFFICER  
USCG RESTRACEN  
YORKTOWN, VA 23690

COMMANDING OFFICER  
USCG RSCH & DEV. CENTER  
GROTON, CT 06340

OCEANOGRAPHIC SERVICES DIV.  
NOAA  
6010 EXECUTIVE BLVD.  
ROCKVILLE, MD 20852

FEDERAL COORD. FOR METEORO.  
SERVS. & SUP. RSCH. (OFCM)  
11426 ROCKVILLE PIKE  
SUITE 300  
ROCKVILLE, MD 20852

NATIONAL CLIMATIC CENTER  
ATTN: L. PRESTON D542X2  
FEDERAL BLDG. - LIBRARY  
ASHEVILLE, NC 28801

DIRECTOR  
NATIONAL OCEANO. DATA CENTER  
E/OC23, NOAA  
WASHINGTON, DC 20235

NOAA RSCH FACILITIES CENTER  
P.O. BOX 520197  
MIAMI, FL 33152

DIRECTOR  
ATLANTIC MARINE CENTER  
COAST & GEODETIC SURVEY, NOAA  
439 W. YORK ST.  
NORFOLK, VA 23510

CHIEF, INTERNATIONAL AFFAIRS  
NATIONAL WEATHER SERVICE  
8060 13TH STREET  
SILVER SPRING, MD 20910

HEAD  
OFFICE OF OCEANO. & LIMNOLOGY  
SMITHSONIAN INSTITUTION  
WASHINGTON, DC 20560

SCRIPPS INSTITUTION OF  
OCEANOGRAPHY, LIBRARY  
DOCUMENTS/REPORTS SECTION  
LA JOLLA, CA 92037

WOODS HOLE OCEANO. INST.  
DOCUMENT LIBRARY LO-206  
WOODS HOLE, MA 02543

SCIENCE APPLICATIONS  
INTERNATIONAL CORP. (SAIC)  
205 MONTECITO AVE.  
MONTEREY, CA 93940

OCEANROUTES, INC.  
680 W. MAUDE AVE.  
SUNNYVALE, CA 94086-3518

MR. W. G. SCHRAMM/WWW  
WORLD METEOROLOGICAL  
ORGANIZATION  
CASE POSTALE #5, CH-1211  
GENEVA, SWITZERLAND

DIRECTOR, INSTITUTE OF  
PHYSICAL OCEANOGRAPHY  
HARALDSGADE 6  
2200 COPENHAGEN N.  
DENMARK

DIRECTOR OF NAVAL  
OCEANO. & METEOROLOGY  
MINISTRY OF DEFENCE  
OLD WAR OFFICE BLDG.  
LONDON, S.W.1. ENGLAND

THE BRITISH LIBRARY  
SCIENCE REFERENCE LIBRARY (A)  
25 SOUTHAMPTON BLDGS.  
CHANCERY LANE  
LONDON WC2A 1AW

MINISTRY OF DEFENCE  
NAVY DEPARTMENT  
ADMIRALTY RESEARCH LAB  
TEDDINGTON, MIDDLESEX  
ENGLAND

COMMANDER IN CHIEF FLEET  
ATTN: STAFF METEOROLOGIST &  
OCEANOGRAPHY OFFICER  
NORTHWOOD, MIDDLESEX HA6 3HP  
ENGLAND

LIBRARY, INSTITUTE OF  
OCEANOGRAPHIC SCIENCES  
ATTN: DIRECTOR  
WORMLEY, GODALMING  
SURREY GU8 5UB, ENGLAND

METEOROLOGIE NATIONALE  
SMM/DOCUMENTATION  
2, AVENUE RAPP  
75340 PARIS CEDEX 07  
FRANCE

SERVICE HYDROGRAPHIQUE ET  
OCEANOGRAPHIQUE DE LA MARINE  
ESTABLISSEMENT PRINCIPAL  
RUE DU CHATELLIER, B.P. 426  
29275 - BREST CEDEX, FRANCE

METEOROLOGIE NATIONALE  
1 QUAI BRANLY  
75, PARIS (7)  
FRANCE

DIRECTION DE LA METEOROLOGIE  
ATTN: J. DETTWILLER, MN/RE  
77 RUE DE SEVRES  
92106 BOULOGNE-BILLANCOURT  
CEDEX, FRANCE

OZEANOGRAPHISCHE  
FORSCHUNGSANSTALT BUNDESWEHR  
LORNSENSTRASSE 7, KIEL  
FEDERAL REPUBLIC OF GERMANY

INSTITUT FUR MEERESKUNDE  
AN DER UNIVERSITAT KIEL  
DUSTERNBROOKER WEG 20  
23 KIEL  
FEDERAL REPUBLIC OF GERMANY

INSTITUT FUR MEERESKUNDE DER  
UNIVERSITAT HAMBURG  
HEIMHUEDERSTRASSE 71  
2000 HAMBURG 13  
FEDERAL REPUBLIC OF GERMANY

DIRECTOR, DEUTSCHES  
HYDROGRAPHISCHES INSTITUT  
TAUSCHSTELLE, POSTFACH 220  
02000 HAMBURG 4  
FEDERAL REPUBLIC OF GERMANY

ISTITUTO UNIVERSITARIO NAVALE  
FACILTA DI SCIENZE NAUTICHE  
ISTITUTO DI METEOROLOGIA E  
OCEANOGRAFIA, 80133 NAPOLI -  
VIA AMM, ACTON, 38 ITALY

CONSIGLIO NAZIONALE DELLE  
RICERCHE  
ISTITUTO TALASSOGRAFICO DI  
TRIESTE, VIALE R. GESSI 2  
34123 TRIESTE, ITALY

DIRECTOR, SACLANT ASW  
RESEARCH CENTRE  
VIALE SAN BARTOLOMEO, 400  
I-19026 LA SPEZIA, ITALY

LMED  
— 8